PLUG DOOR STUDY SUMMARY

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BACKGROUND

- sPHENIX, fsPHENIX, etc. will use the BABAR magnet to generate a magnetic field in the interaction region for tracking, etc.
- The magnetic field generated needs to have a flux return to ensure a smooth magnetic field.
- There are two designs for the magnetic field flux return.
  - One uses an iron cylindrical block called the plug door
  - The other is to use a magnetic hadron calorimeter.
- This study will focus on the first option and a drawing of the detector with the plug doors or flux returns is shown on the next slide

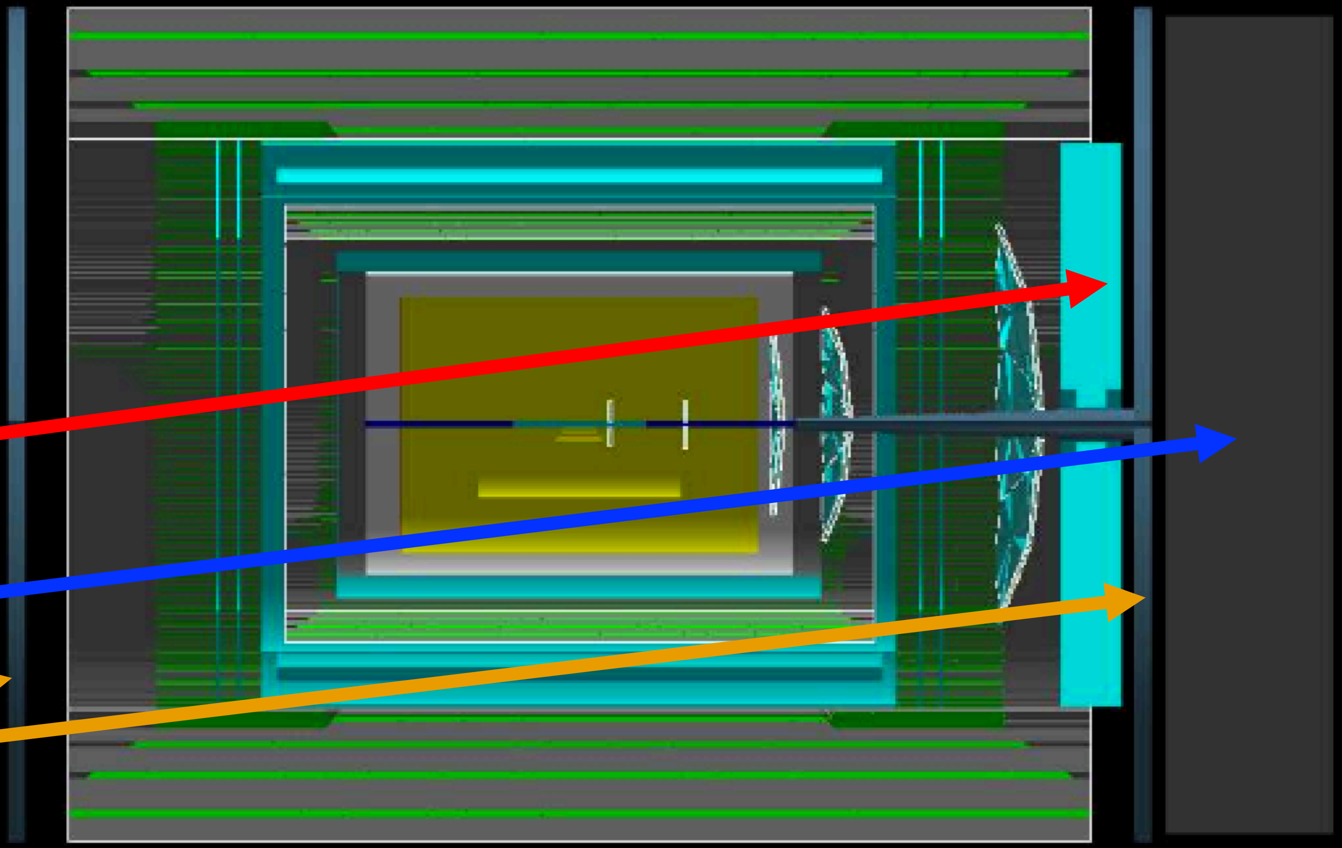
DETECTOR GEOMETRY FOR FSPHENIX

- The figure on the right is what the detector geometry looks like for a Flux Return of 10.2 cm.

Forward Electromagnetic Calorimeter (FEMC)

Forward Hadron Calorimeter (FHCAL)

Flux Returns
(AKA: Plug Door)



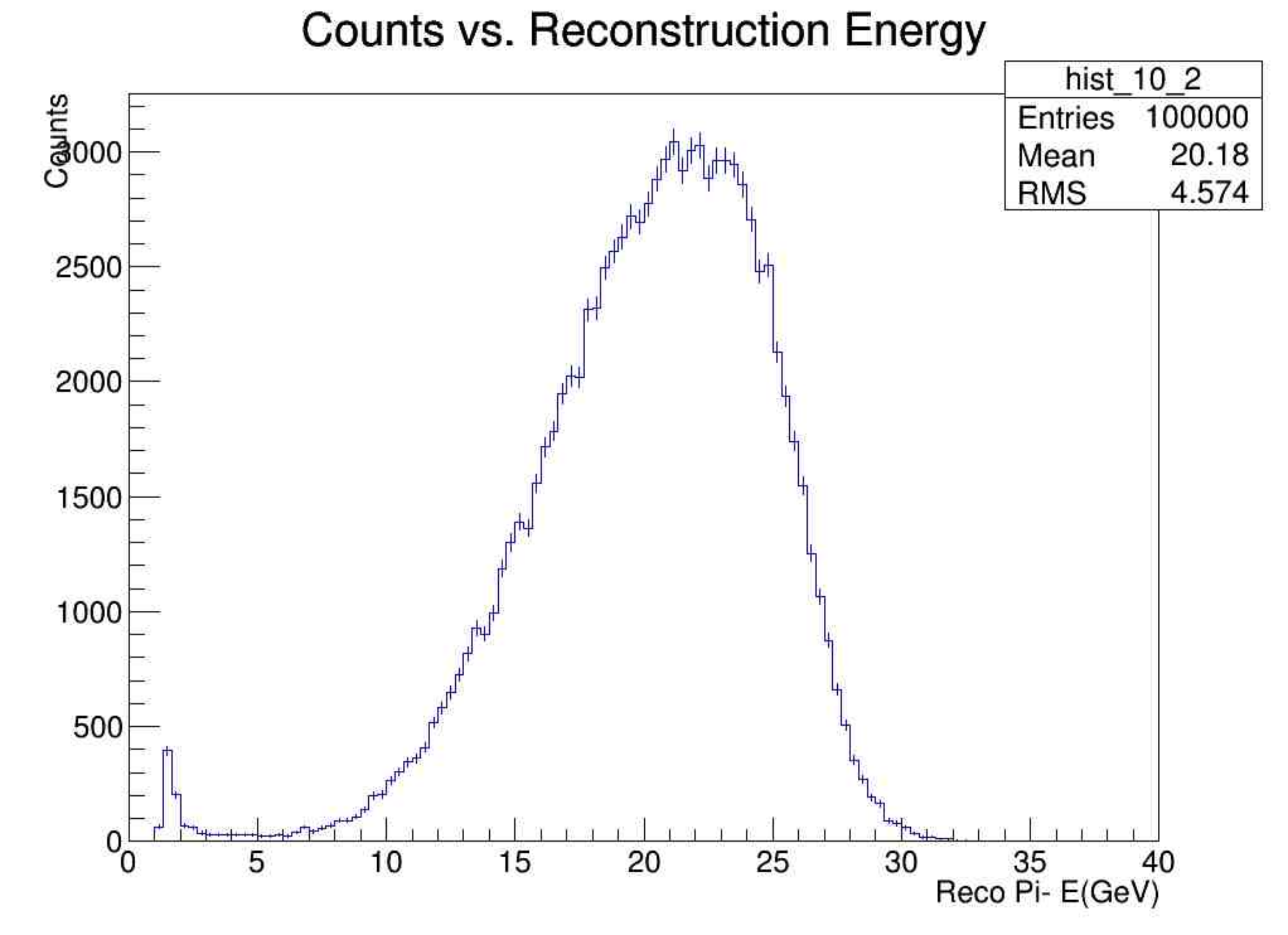
GOAL OF STUDY

- The option of using a plug door means that there is dead material between the Hadron Calorimeter and the Electromagnetic calorimeter as shown on the last slide.
- This dead material will affect the energy measured by the Hadron Calorimeter.
- The purpose of this study to find out by how much the plug door will affect our ability to measure the energy of particles in the hadron calorimeter
- In order to do this we need run simulations with the plug door at different thicknesses to understand where and at what energies does the plug door begin to matter

FIRST STEPS

- Modify fsPHENIX Fun4All file to generate pions (π^-) at a pseudorapidity (η) of 2.0, well within the region of both the FEMC and FHCAL
- The energy of the pions were initially chosen arbitrarily to be 30.0 GeV.
- The thickness or length of the plug door was chosen to be 10.2 cm the currently proposed length
- First started by looking at about 100 events then 10,000 and now I generate 100,000 events for each thickness and energy that I simulate
- Once simulations were complete I made histograms for the total energy absorbed by both the FEMC and FHCAL.

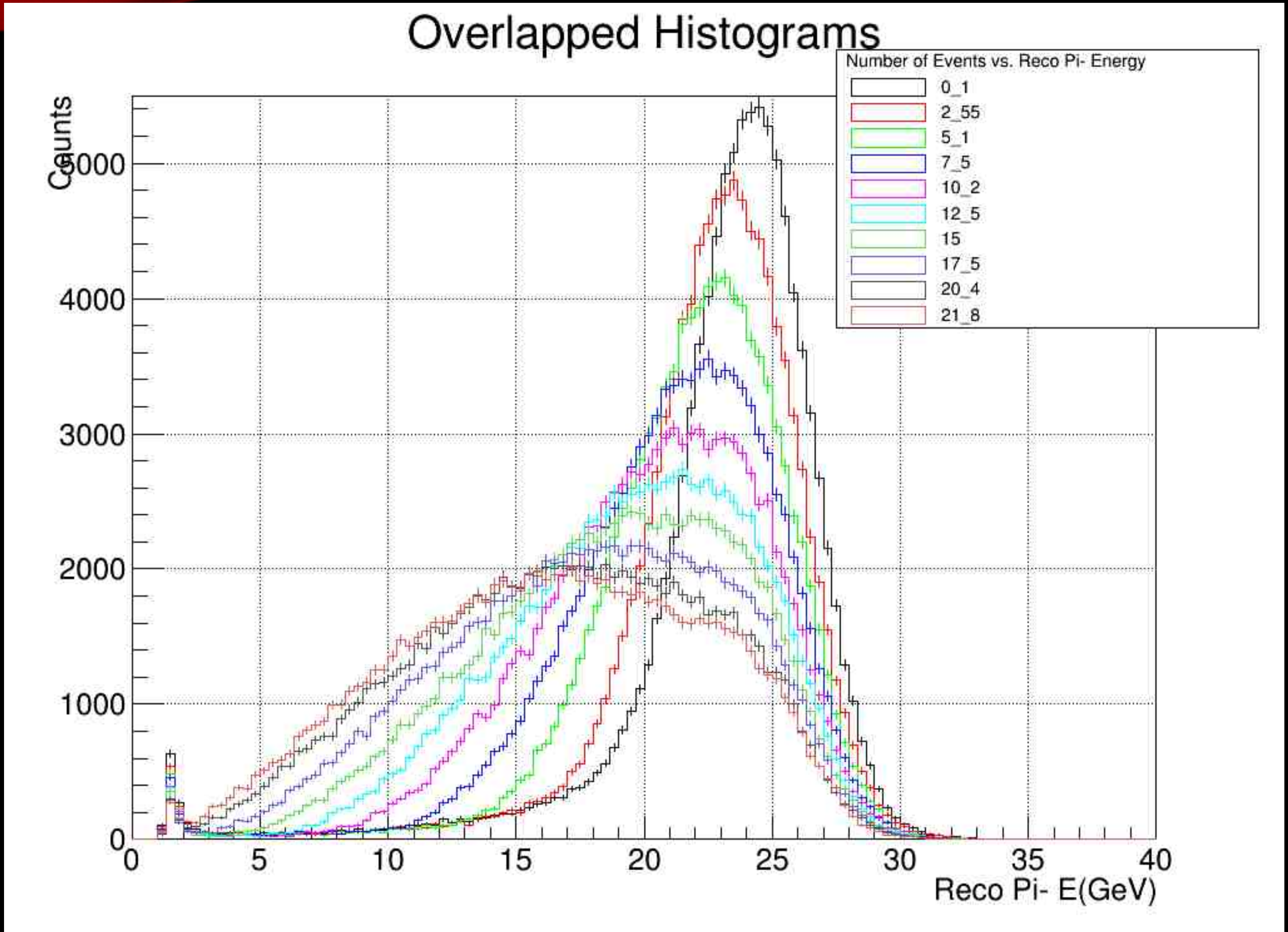
10.2 CM 30 GEV PION



CONTINUING SIMULATIONS

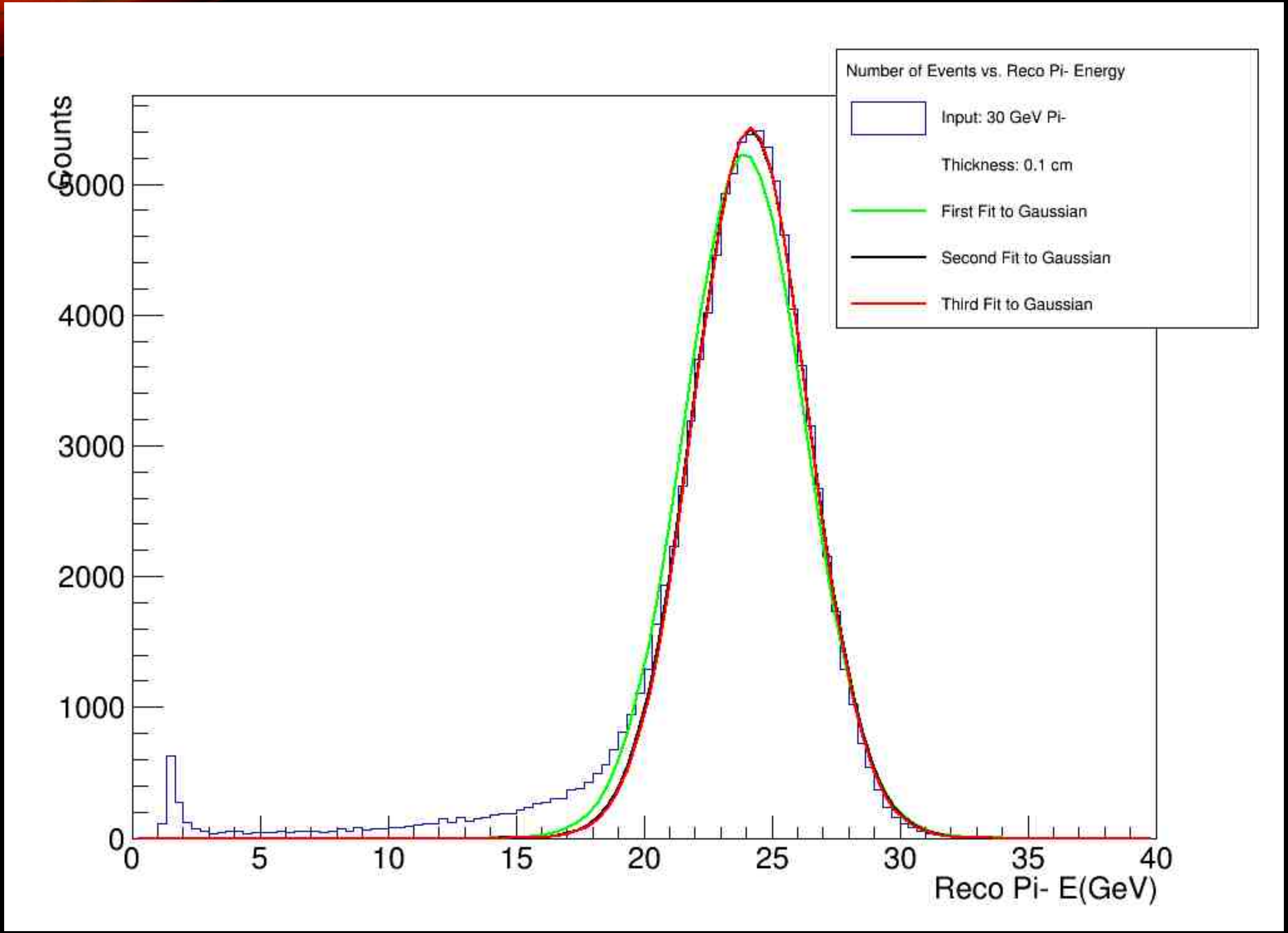
- To understand how the plug door is affecting the energy for other thickness more simulations were needed
- The thicknesses I ran was: 0.1, 2.55, 5.1, 7.5, 10.2, 12.5, 15, 17.5, 20.4, 21.8 cm
    - 21.8 cm is the limit before the door overlaps with the FHCAL
- The next slide shows the overlapped histogram from all of these thicknesses
    - In the legend the underscore ("_") character is equivalent to a dot (".") so "7_5" means a thickness of 7.5 cm

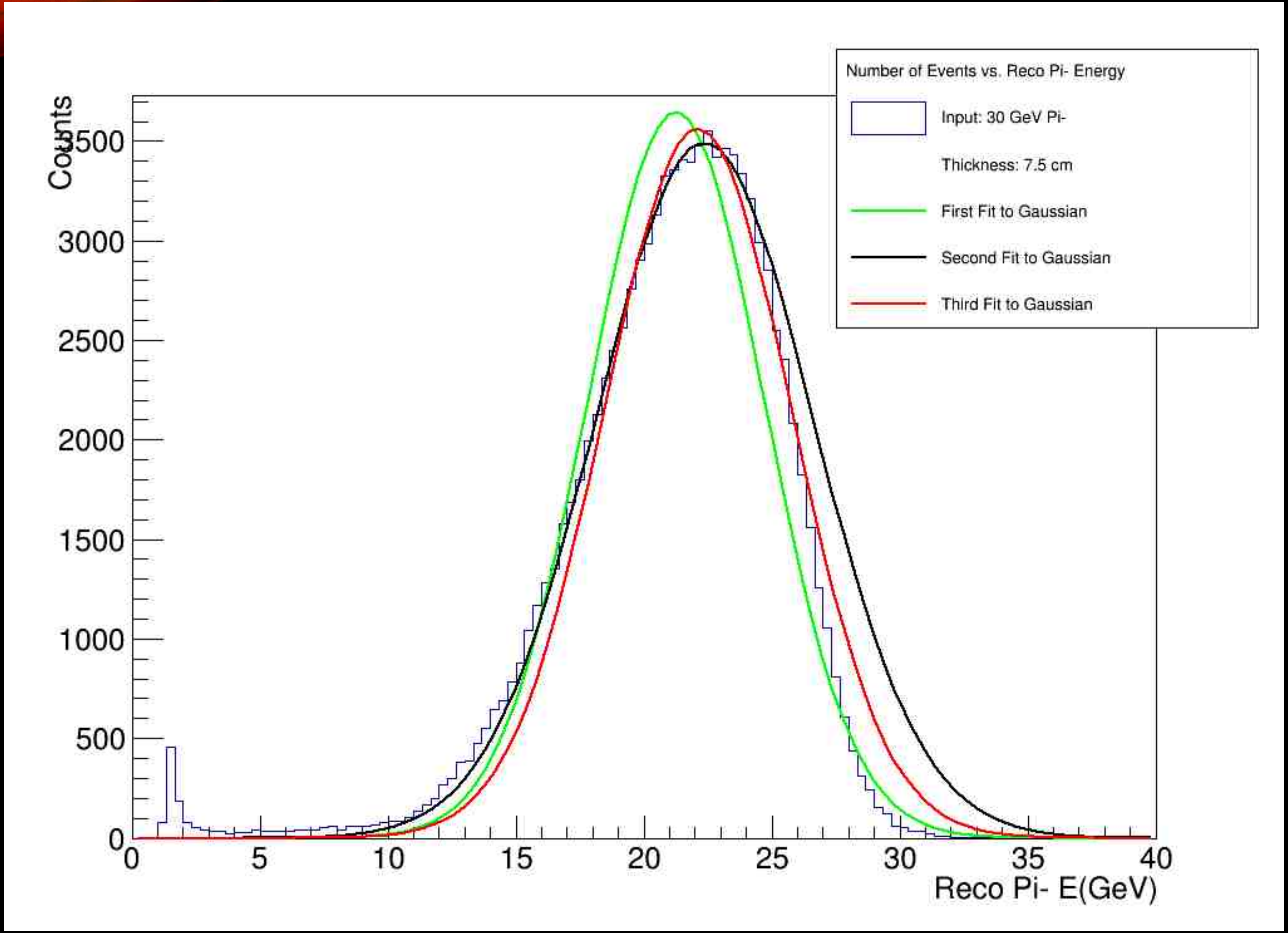
OVERLAPPED HISTOGRAMS 30 GEV PIONS

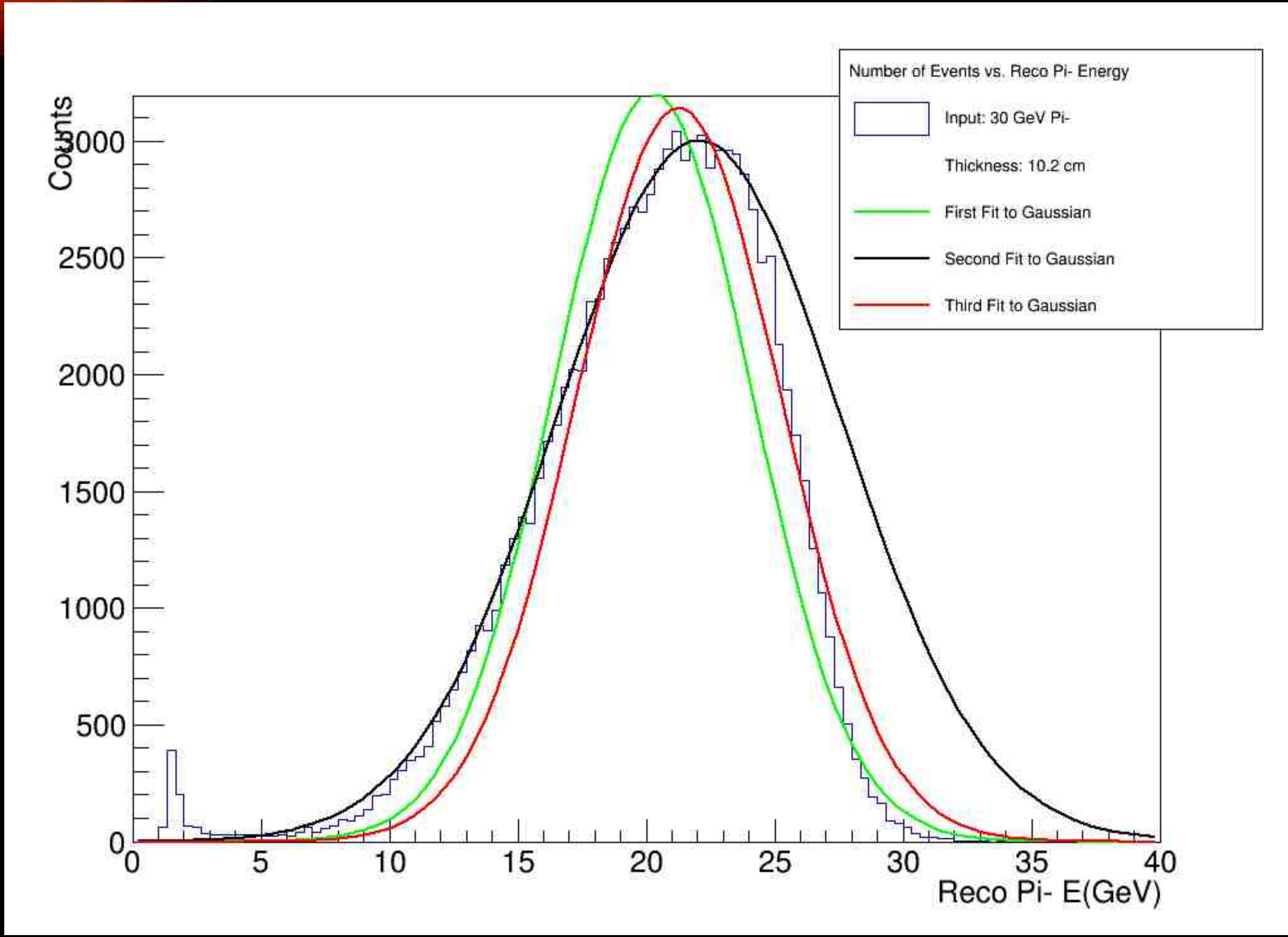


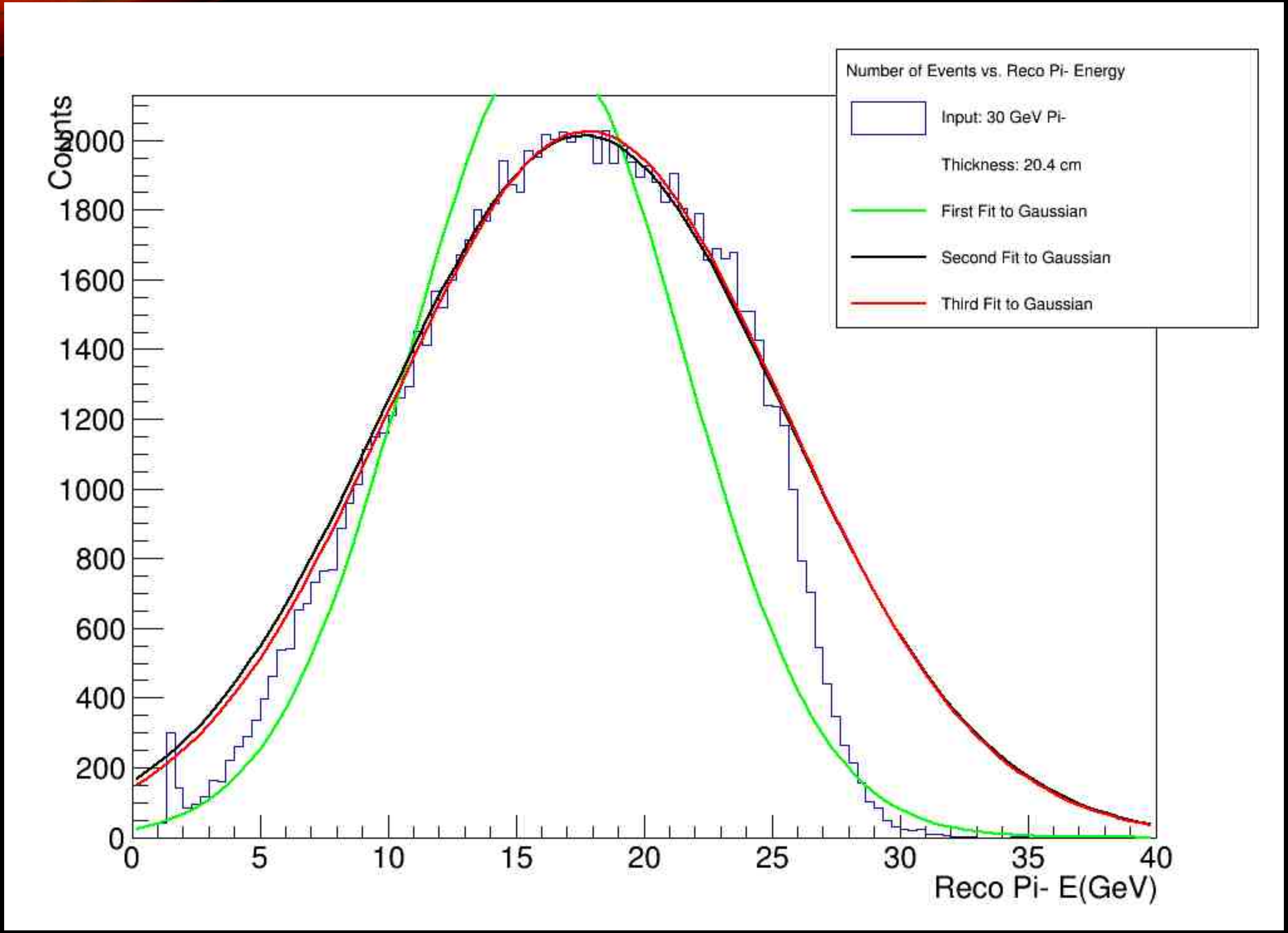
WHAT TO DO NEXT

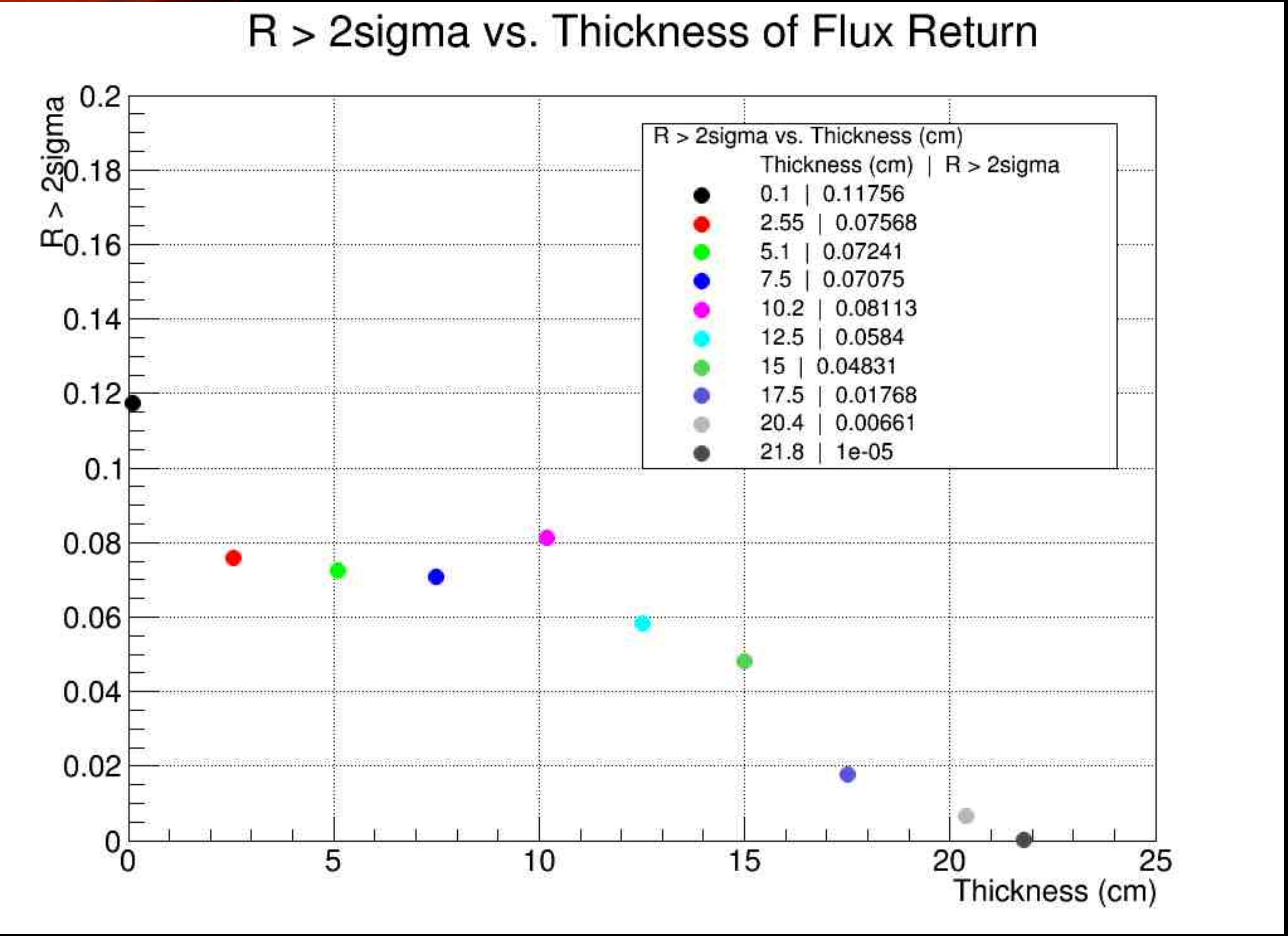
- Started to fit the histograms from those thicknesses to a Gaussian.
- To fit the histogram the following method was used
  - First fit was done on whole range of histogram
  - Second fit is done on the range $\mu_{fit}\pm\sigma_{fit}$ from the first fit
  - Third fit is done on the range $\mu_{fit}\pm\sigma_{fit}$ from the second fit
- The reason for doing this was to isolate the tail by using a Gaussian fit to get the mean and sigma then everything outside of 2 sigma would be the tail
- The tail region would be integrated and divided by the total number of events to get the percentage of values in the tail.
  - This value would be called “R” or “R > 2sigma” as seen on the slides below
- The backup slides and the slides below contain the histograms with the fits, and the “R” value, the fit mean, the fit sigma, and the fit sigma/mean vs. thickness for those fits from 30 GeV pion simulations

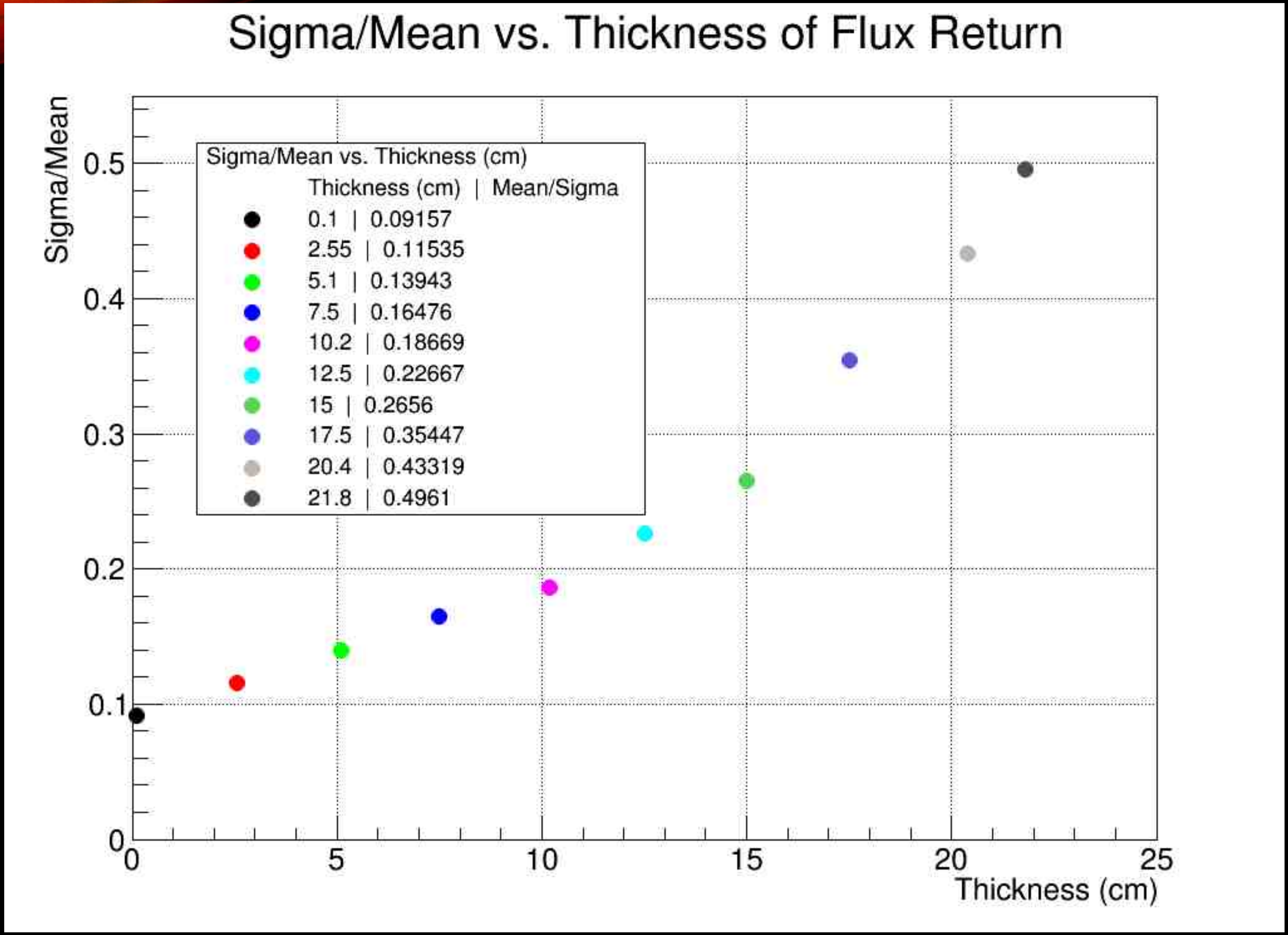

Number of Events vs. Reco Pi- Energy
Input: 30 GeV Pi-
Thickness: 0.1 cm
First Fit to Gaussian
Second Fit to Gaussian
Third Fit to Gaussian
Counts
5000
4000
3000
2000
1000
0
0
5
10
15
20
25
30
35
40
Reco Pi- E(GeV)


Number of Events vs. Reco Pi- Energy
Input: 30 GeV Pi-
Thickness: 7.5 cm
First Fit to Gaussian
Second Fit to Gaussian
Third Fit to Gaussian
Counts
0
500
1000
1500
2000
2500
3000
3500
0
5
10
15
20
25
30
35
40
Reco Pi- E(GeV)


Number of Events vs. Reco Pi- Energy
Input: 30 GeV Pi-
Thickness: 10.2 cm
First Fit to Gaussian
Second Fit to Gaussian
Third Fit to Gaussian
Counts
0
500
1000
1500
2000
2500
3000
0
5
10
15
20
25
30
35
40
Reco Pi- E(GeV)


Number of Events vs. Reco Pi- Energy
Input: 30 GeV Pi-
Thickness: 20.4 cm
First Fit to Gaussian
Second Fit to Gaussian
Third Fit to Gaussian
Counts
0
200
400
600
800
1000
1200
1400
1600
1800
2000
0
5
10
15
20
25
30
35
40
Reco Pi- E(GeV)

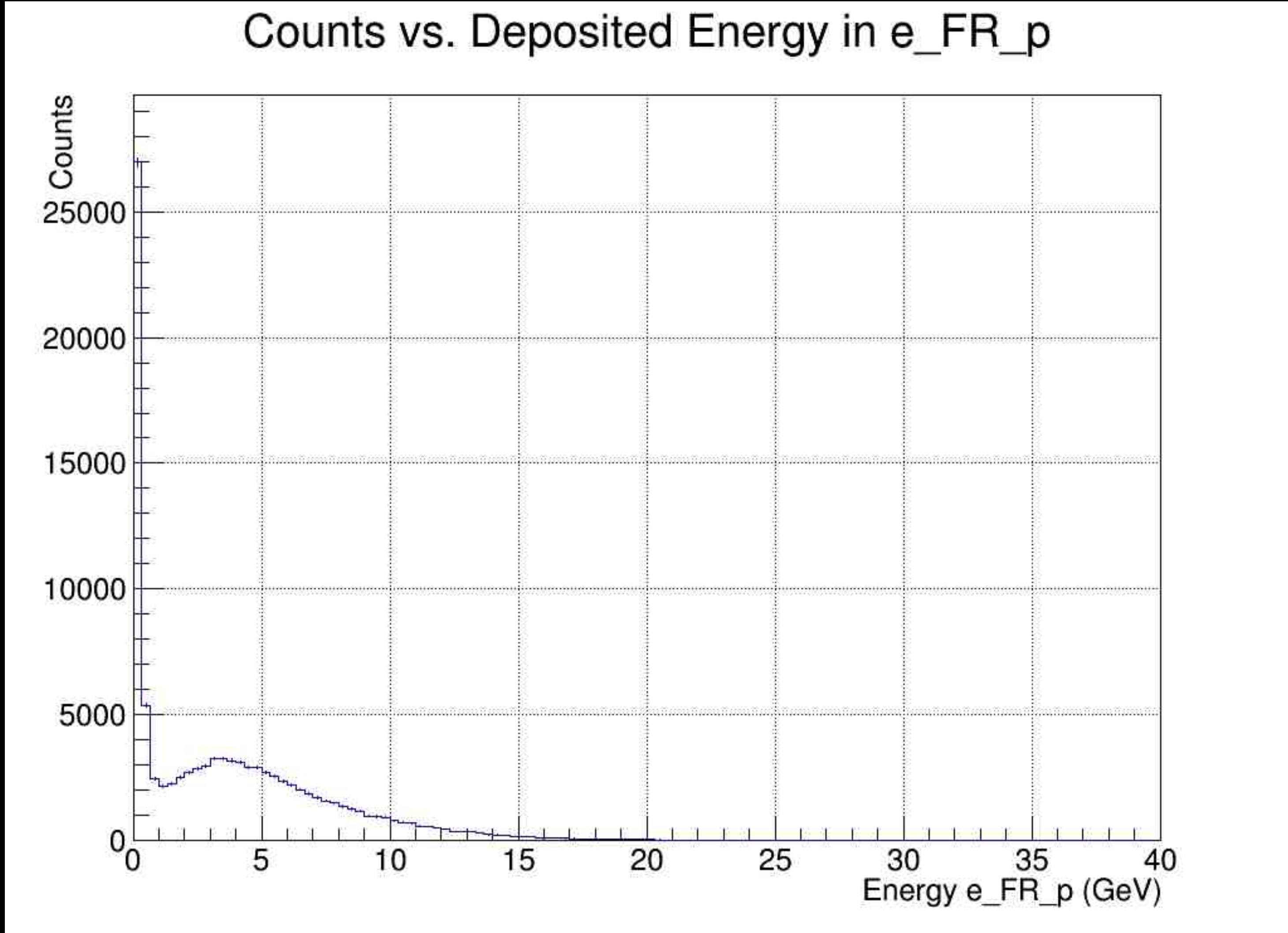

R > 2sigma vs. Thickness of Flux Return
R > 2sigma
Thickness (cm)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
5
10
15
20
25
R > 2sigma vs. Thickness (cm)
Thickness (cm) | R > 2sigma
0.1 | 0.11756
2.55 | 0.07568
5.1 | 0.07241
7.5 | 0.07075
10.2 | 0.08113
12.5 | 0.0584
15 | 0.04831
17.5 | 0.01768
20.4 | 0.00661
21.8 | 1e-05


Sigma/Mean vs. Thickness of Flux Return
Sigma/Mean
Thickness (cm)
Sigma/Mean vs. Thickness (cm)
Thickness (cm) | Mean/Sigma
0.1 | 0.09157
2.55 | 0.11535
5.1 | 0.13943
7.5 | 0.16476
10.2 | 0.18669
12.5 | 0.22667
15 | 0.2656
17.5 | 0.35447
20.4 | 0.43319
21.8 | 0.4961
0
0.1
0.2
0.3
0.4
0.5
0
5
10
15
20
25

SUCCESS AND FAILURE

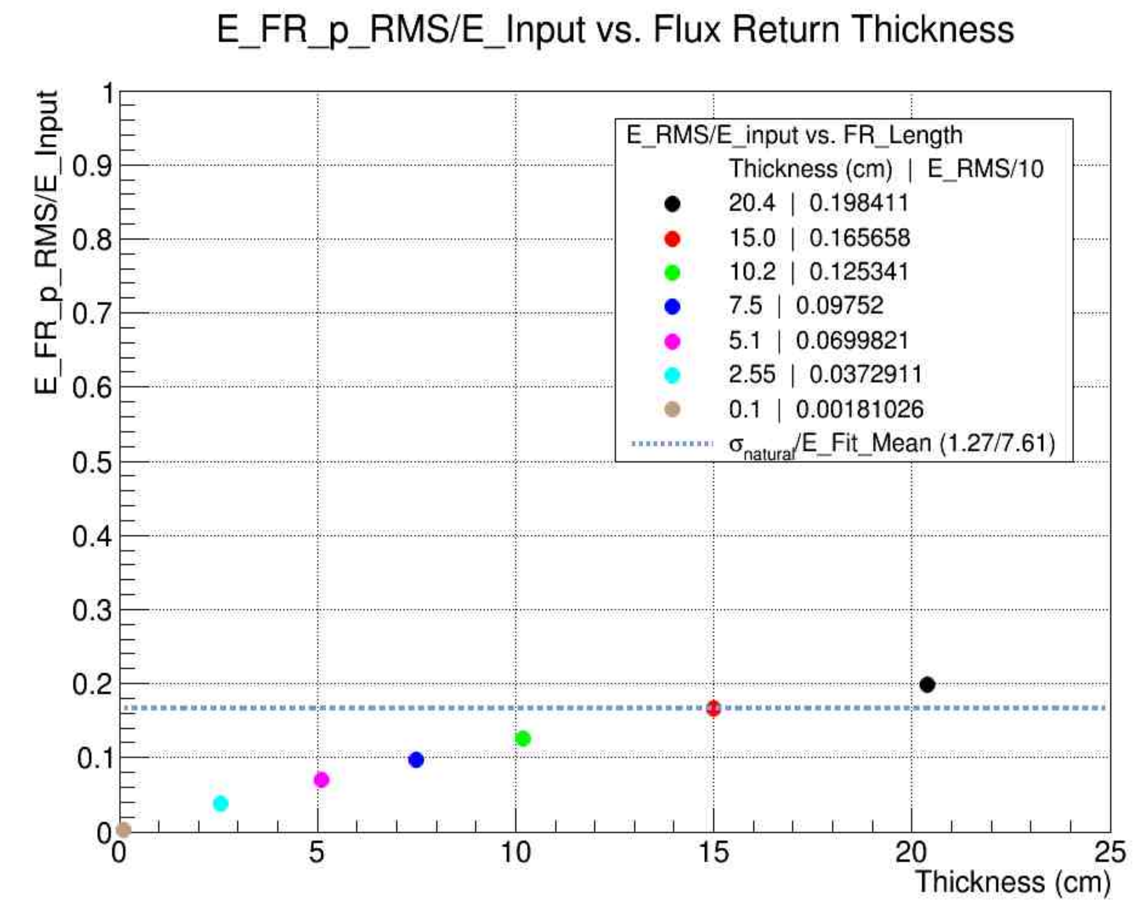
- From the plots it is clear that at thicknesses less than or equal to 7.5 cm the Gaussian does a great job of encompassing the peak and isolating the tail
- For thicknesses greater than about 7.5 cm the behavior becomes non Gaussian and perhaps even a second peak develops.
- This means we can't do a simple Gaussian fit to isolate the tail
- A new way to characterize the plug door is needed.
- This can be done by looking at the energy deposited in the flux return itself
- To do this I wrote a module which can be found on github under the sphenix collaboration: /analysis/ForwardCalo/Flux_Return_Study
  - Module can be used to get energy from various sources see README for more info
- Histograms were made of this energy as before for the calorimeters and can be found on the slide below

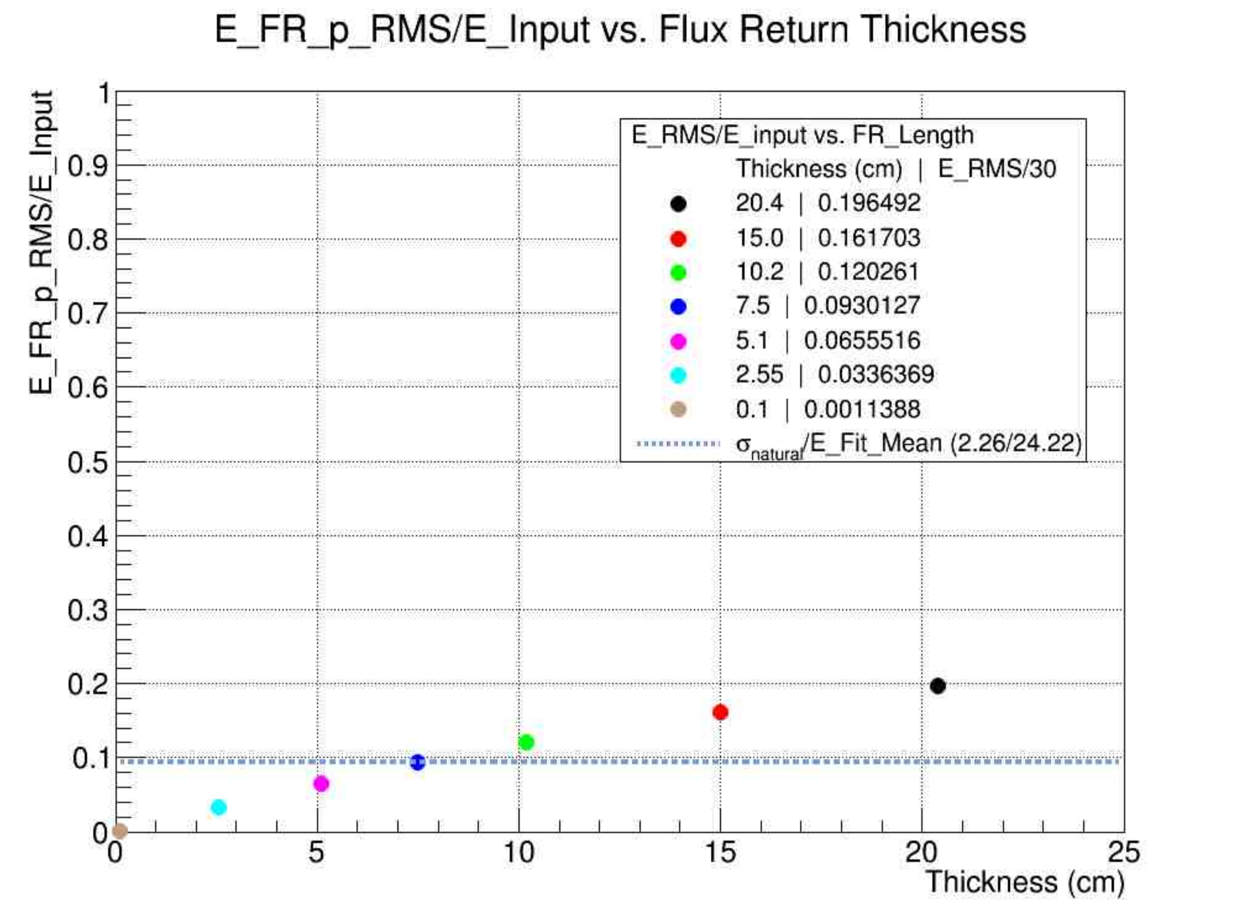
10.2 CM 30 GEV PIONS ENERGY DEPOSITED IN FORWARD FLUX RETURN

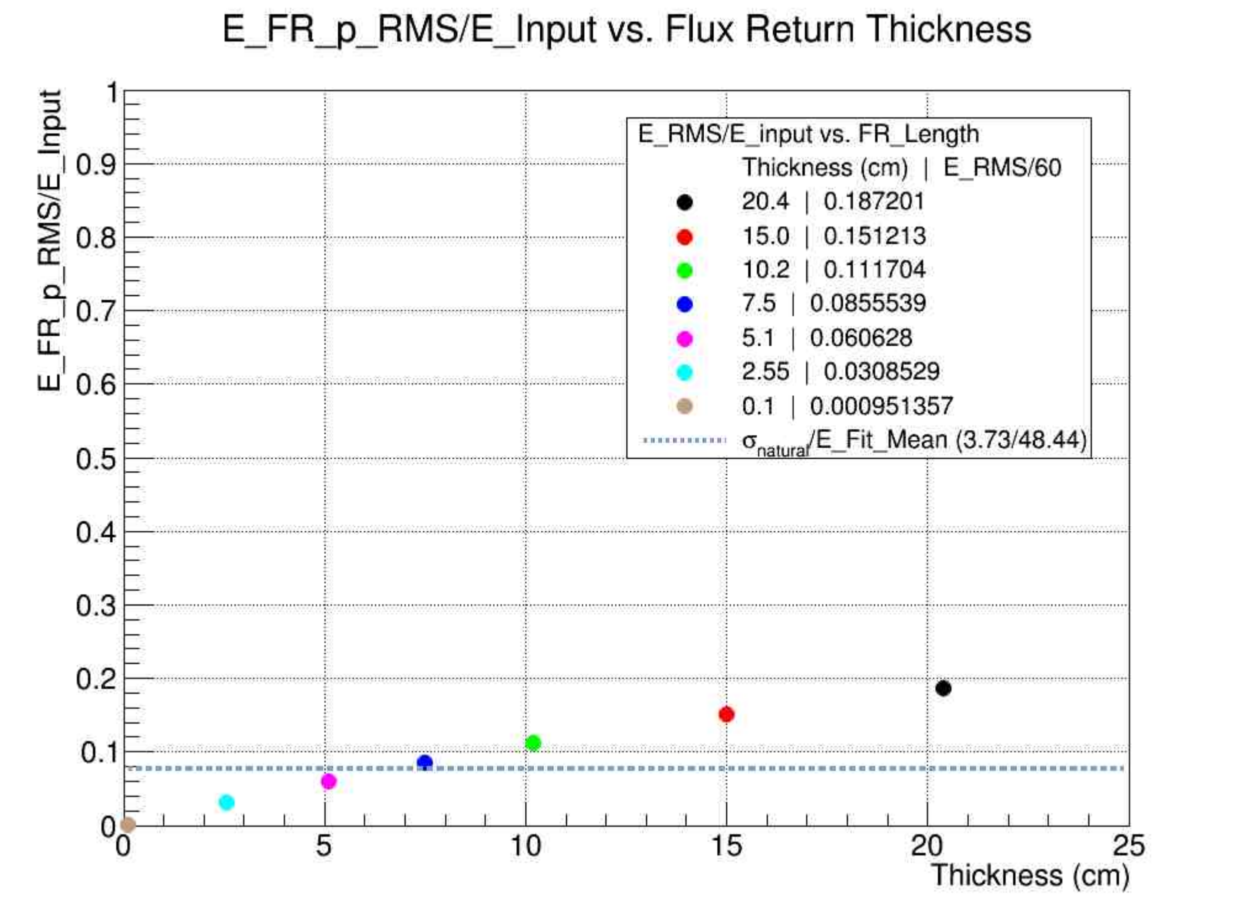


ALMOST THERE

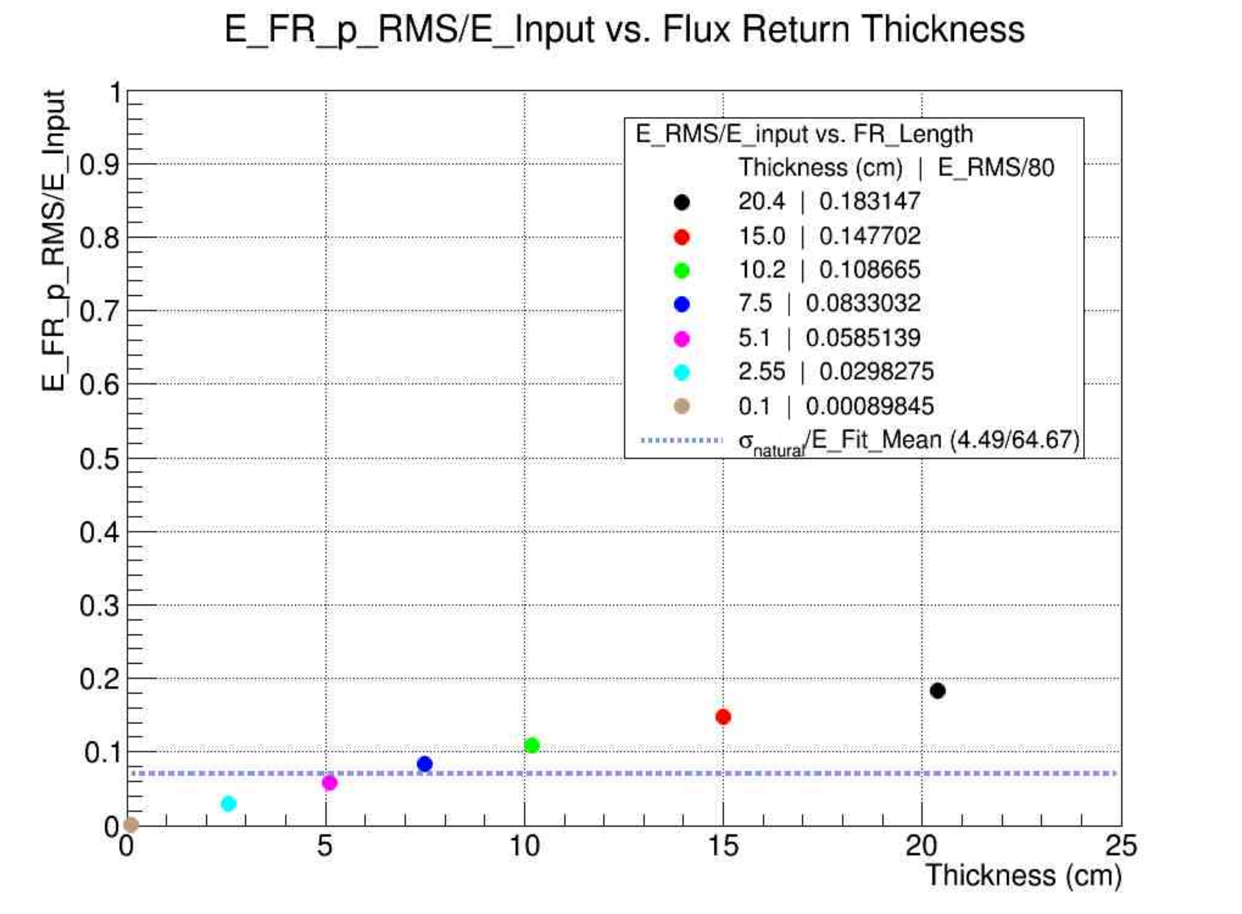
- Now that we have the energy deposited in the plug door we can make plots of E/E_input vs. Flux Return Thickness
  - The E will be either the mean for the energies from the calorimeters or flux return or the RMS of the histogram for those energies
  - E_input will be the energy of the incoming pion
- The Idea is to see at which thickness the resolution of the calorimeters exceed that of the Flux Return
- To get the natural or clean resolution of the calorimeters the millimeter thickness histogram is fitted to a Gaussian using the method described
  - The sigma from this fit is taken as the natural resolution ($\sigma_{natural}$) and then divided by the mean from the fit (E_Fit_Mean)
  - This number is the reference point
- These plots can be found below and on the backup slides


E_FR_p_RMS/E_Input vs. Flux Return Thickness
E_FR_p_RMS/E_Input
Thickness (cm)
E_RMS/E_input vs. FR_Length
Thickness (cm) | E_RMS/10
20.4 | 0.198411
15.0 | 0.165658
10.2 | 0.125341
7.5 | 0.09752
5.1 | 0.0699821
2.55 | 0.0372911
0.1 | 0.00181026
$\sigma_{natural}$/E_Fit_Mean (1.27/7.61)


E_FR_p_RMS/E_Input vs. Flux Return Thickness
E_FR_p_RMS/E_Input
Thickness (cm)
E_RMS/E_input vs. FR_Length
Thickness (cm) | E_RMS/30
20.4 | 0.196492
15.0 | 0.161703
10.2 | 0.120261
7.5 | 0.0930127
5.1 | 0.0655516
2.55 | 0.0336369
0.1 | 0.0011388
$\sigma_{natural}$/E_Fit_Mean (2.26/24.22)



E_FR_p_RMS/E_Input vs. Flux Return Thickness
E_FR_p_RMS/E_Input
Thickness (cm)
E_RMS/E_input vs. FR_Length
Thickness (cm) | E_RMS/60
20.4 | 0.187201
15.0 | 0.151213
10.2 | 0.111704
7.5 | 0.0855539
5.1 | 0.060628
2.55 | 0.0308529
0.1 | 0.000951357
$\sigma_{natural}$/E_Fit_Mean (3.73/48.44)



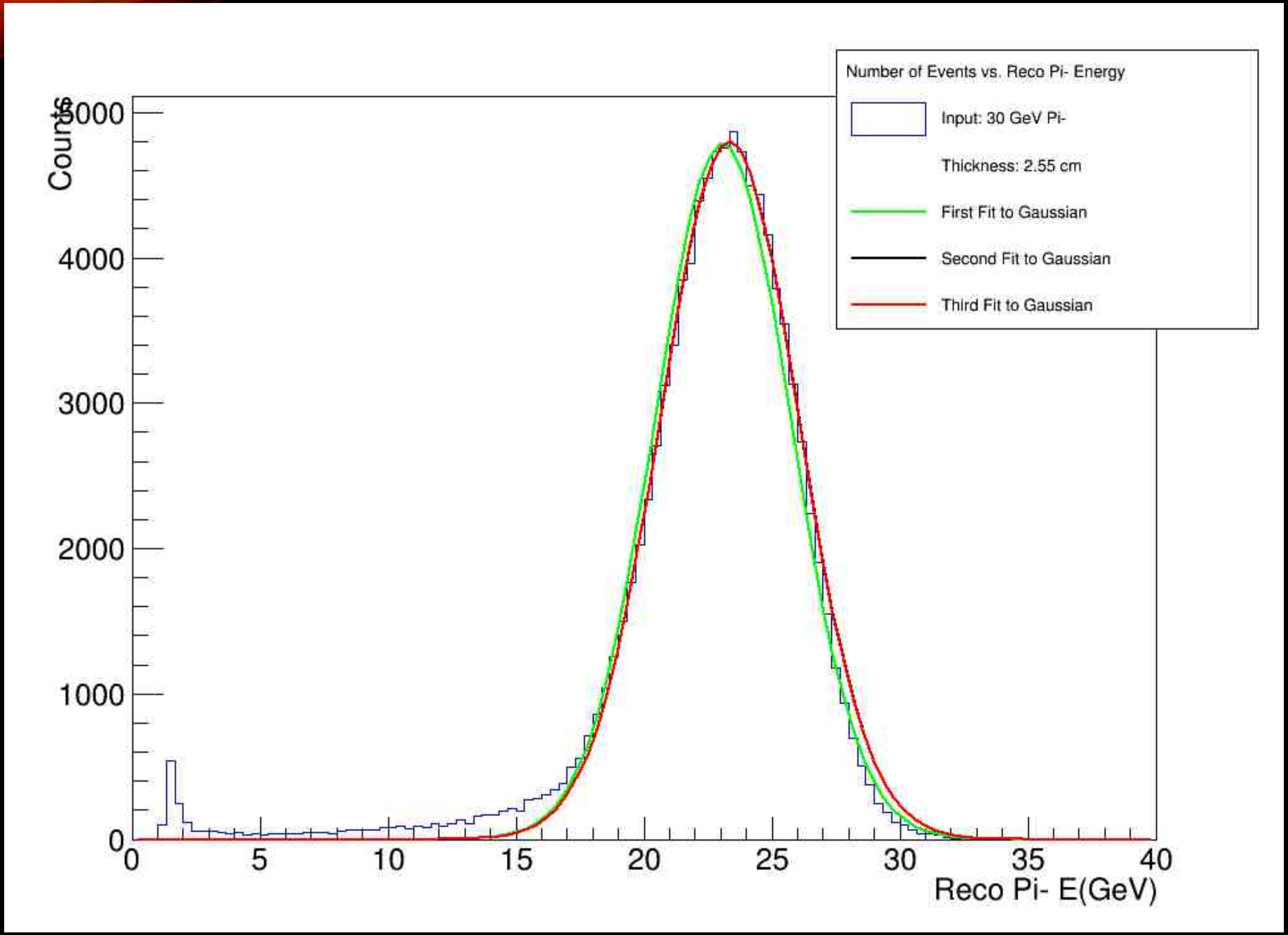
E_FR_p_RMS/E_Input vs. Flux Return Thickness
E_FR_p_RMS/E_Input
Thickness (cm)
E_RMS/E_input vs. FR_Length
Thickness (cm) | E_RMS/80
20.4 | 0.183147
15.0 | 0.147702
10.2 | 0.108665
7.5 | 0.0833032
5.1 | 0.0585139
2.55 | 0.0298275
0.1 | 0.00089845
$\sigma_{natural}$/E_Fit_Mean (4.49/64.67)

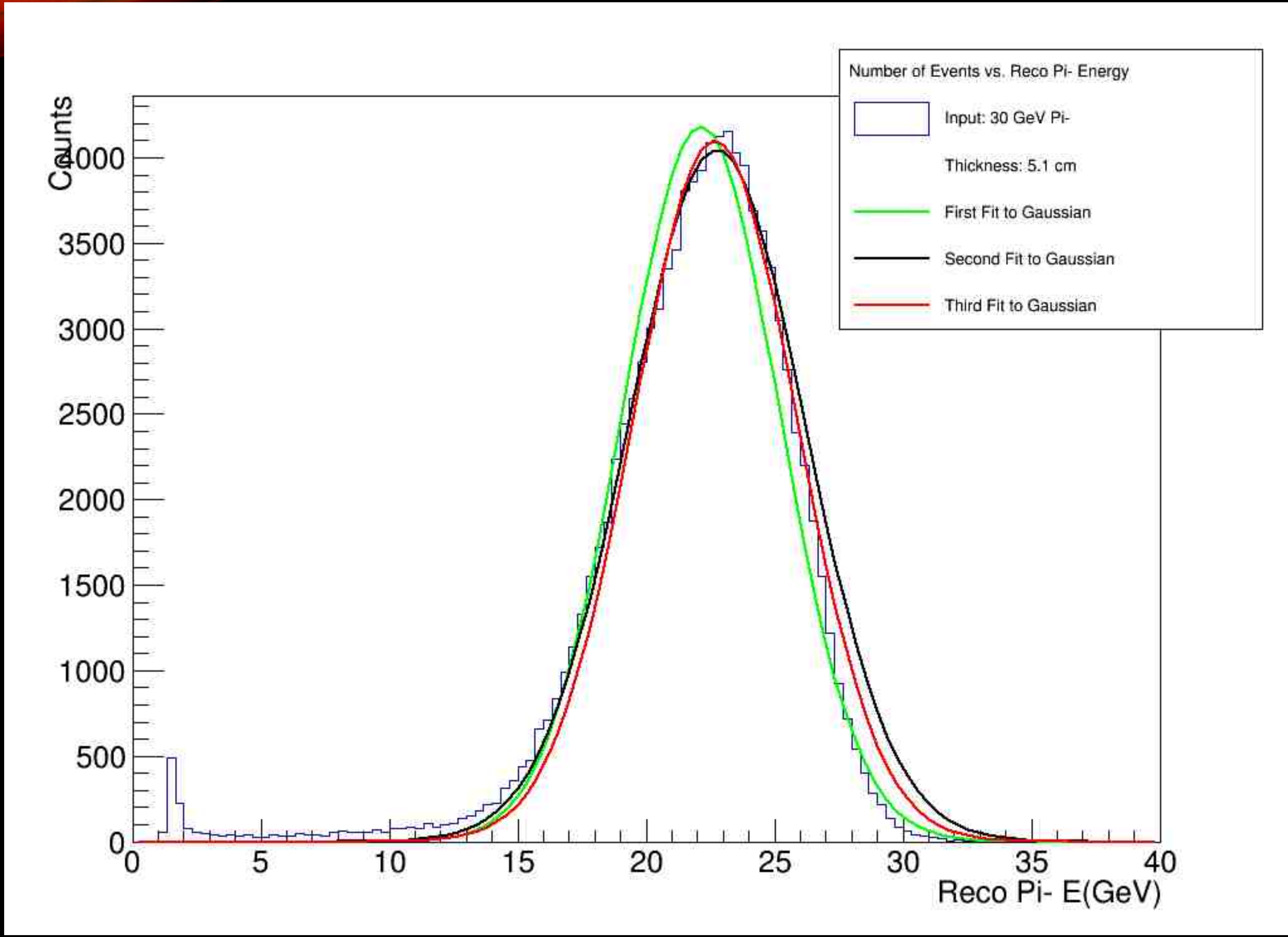
CONCLUSIONS

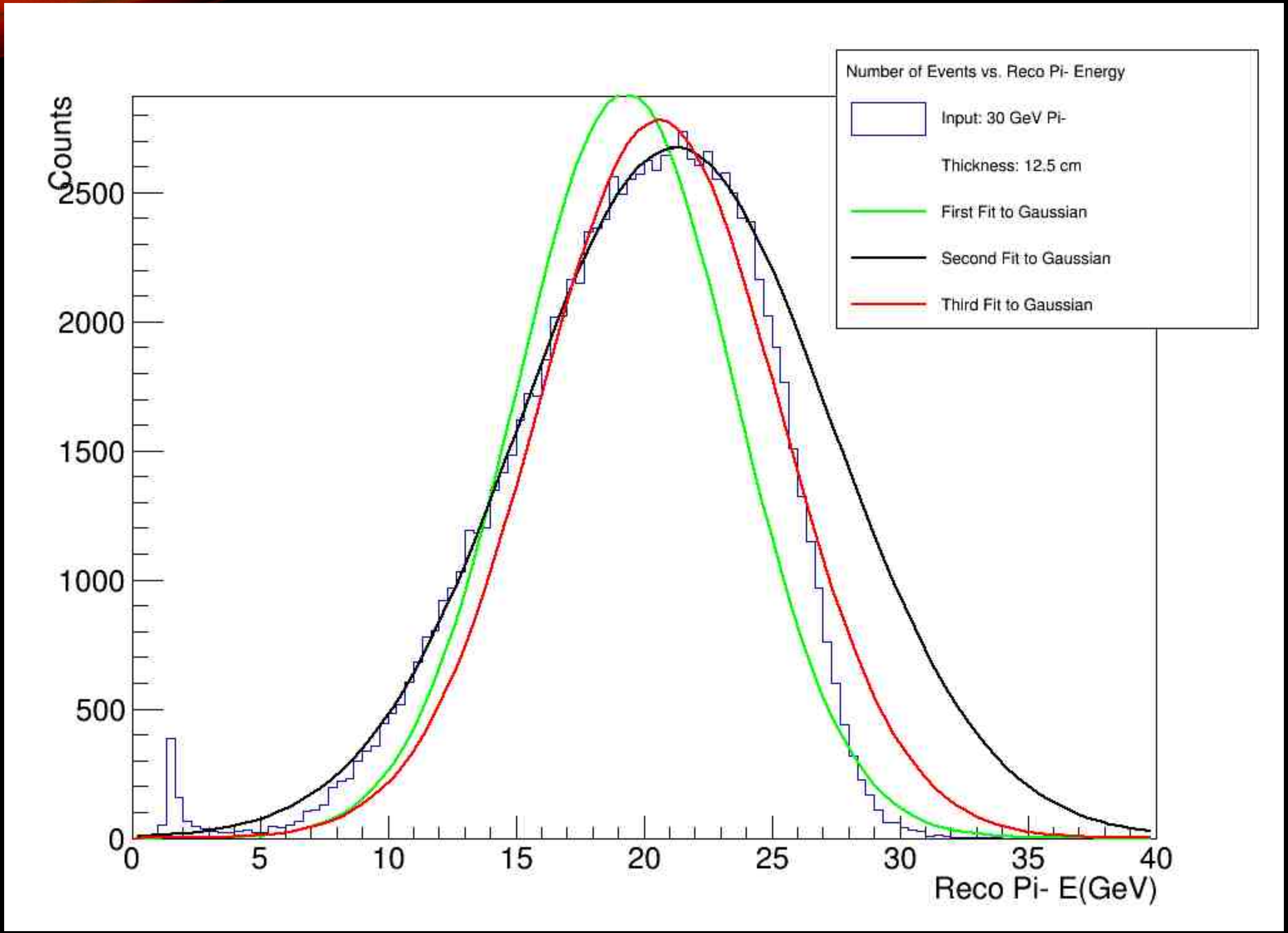
- As can be seen from the plots above only for 10 GeV pions the resolution of the detector is not affected by a plug door of thickness 10.2 cm
- As the energies of the incoming pions increases the tolerable thickness goes down to about 7.5 cm.
- This data seems to complement the data from the fits because at around this thickness the fits started to become less Gaussian
- This clearly indicates that at approximately 7.5 cm the plug door begins to effect the measured energy and energy resolution

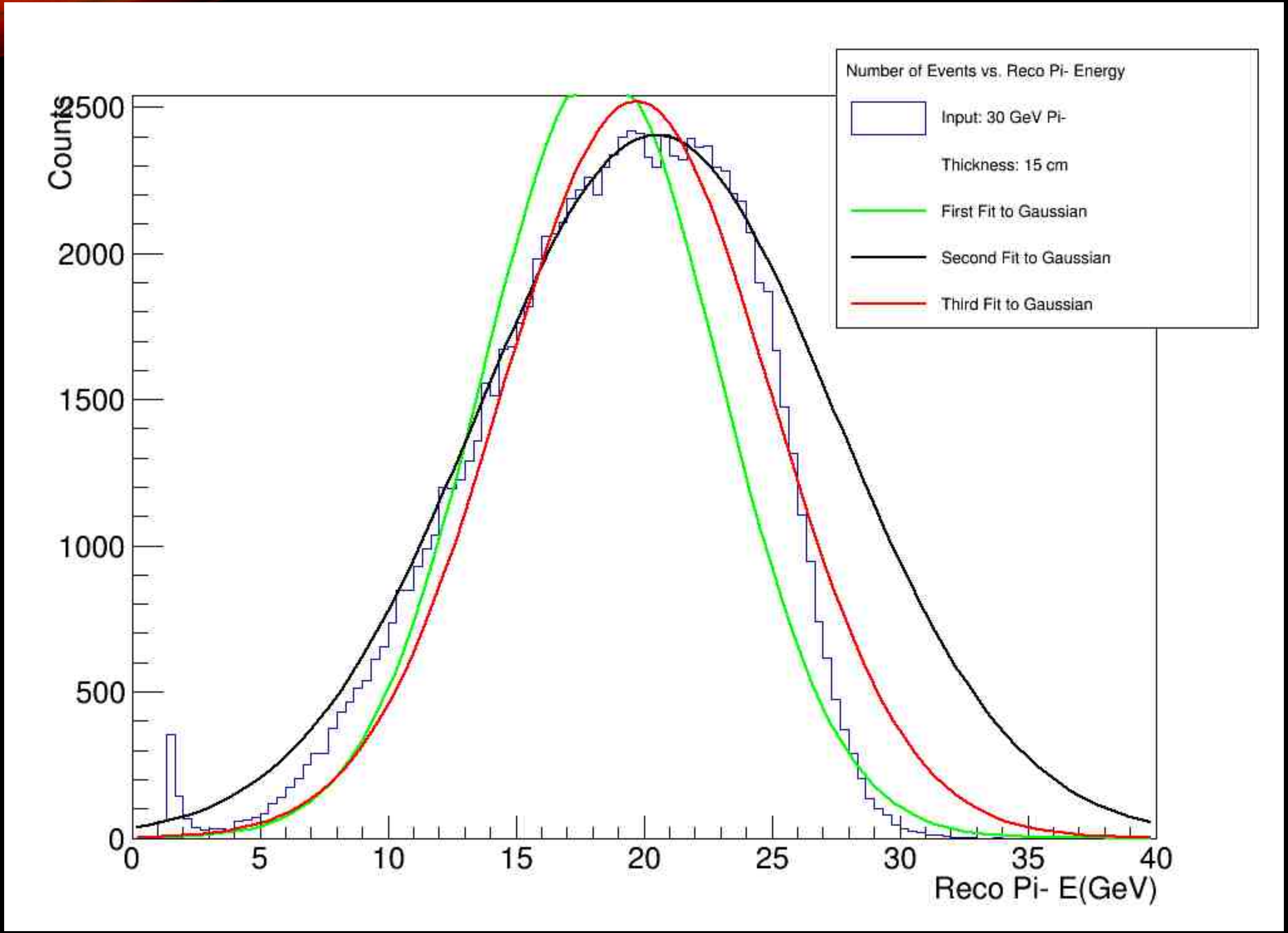
BACKUP SLIDES

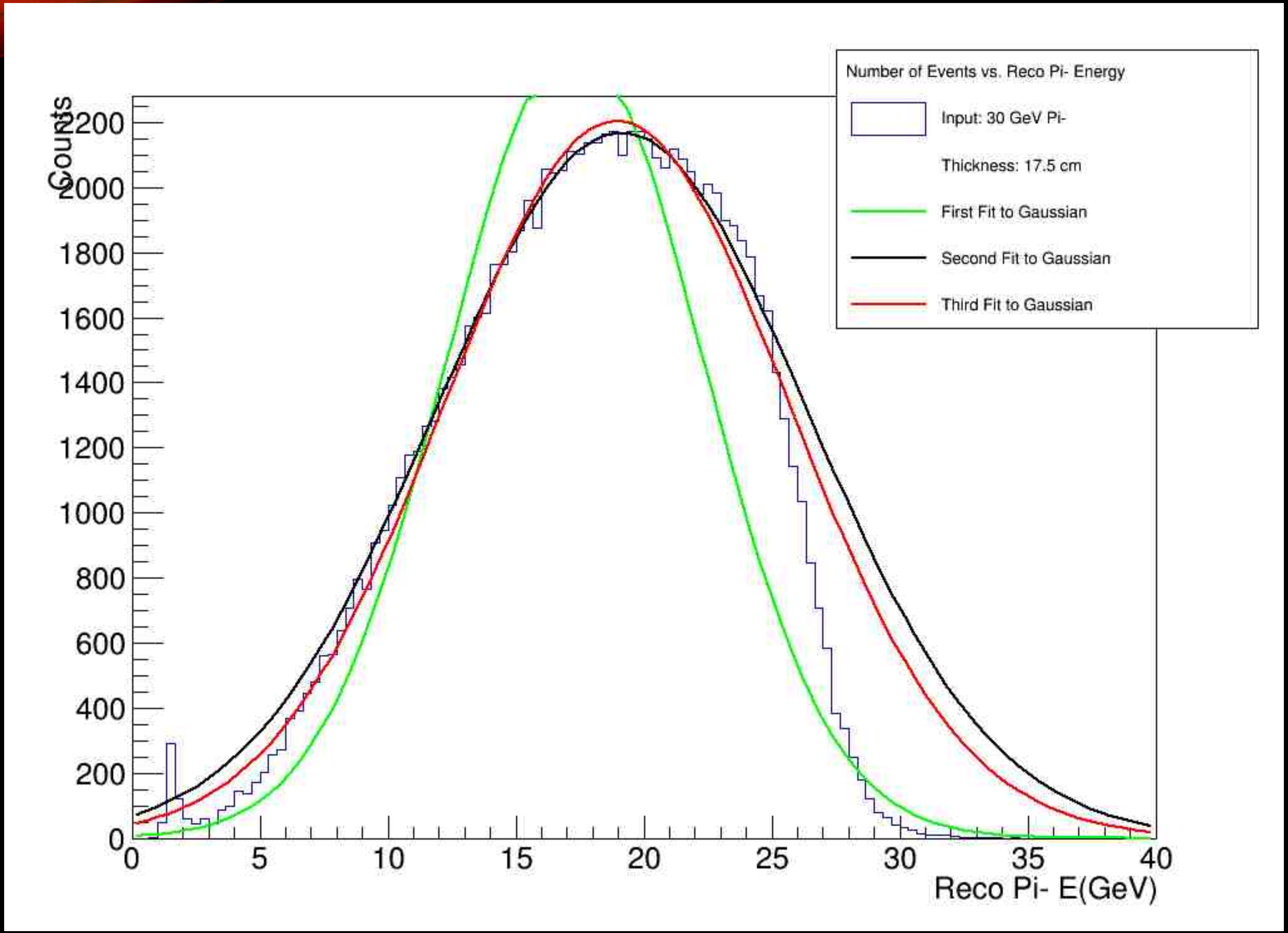
EXTRA GAUSSIAN FIT PLOTS

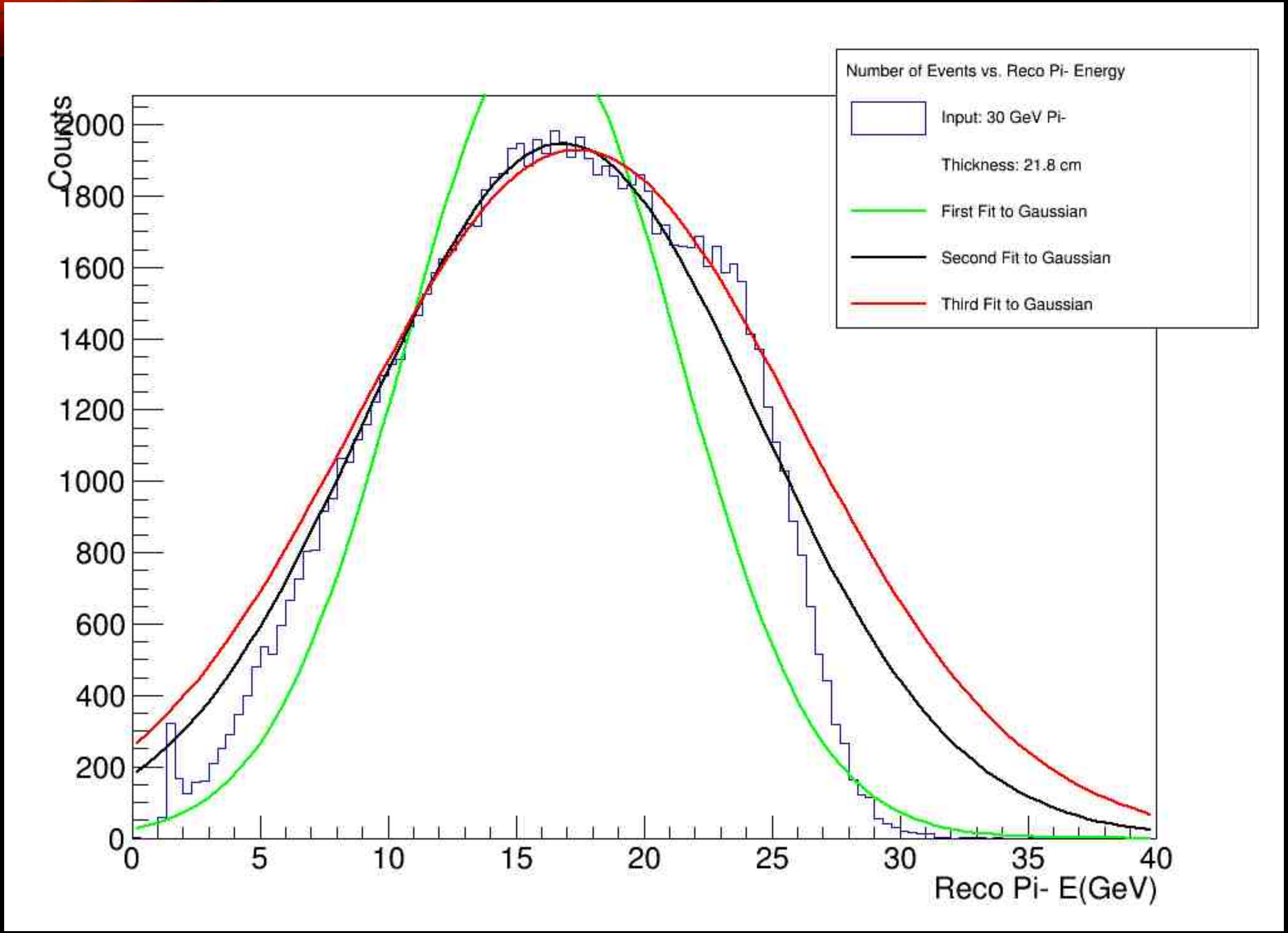

Number of Events vs. Reco Pi- Energy
Input: 30 GeV Pi-
Thickness: 2.55 cm
First Fit to Gaussian
Second Fit to Gaussian
Third Fit to Gaussian
Counts
0
1000
2000
3000
4000
5000
0
5
10
15
20
25
30
35
40
Reco Pi- E(GeV)


Number of Events vs. Reco Pi- Energy
Input: 30 GeV Pi-
Thickness: 5.1 cm
First Fit to Gaussian
Second Fit to Gaussian
Third Fit to Gaussian
Counts
Reco Pi- E(GeV)
0
500
1000
1500
2000
2500
3000
3500
4000
0
5
10
15
20
25
30
35
40

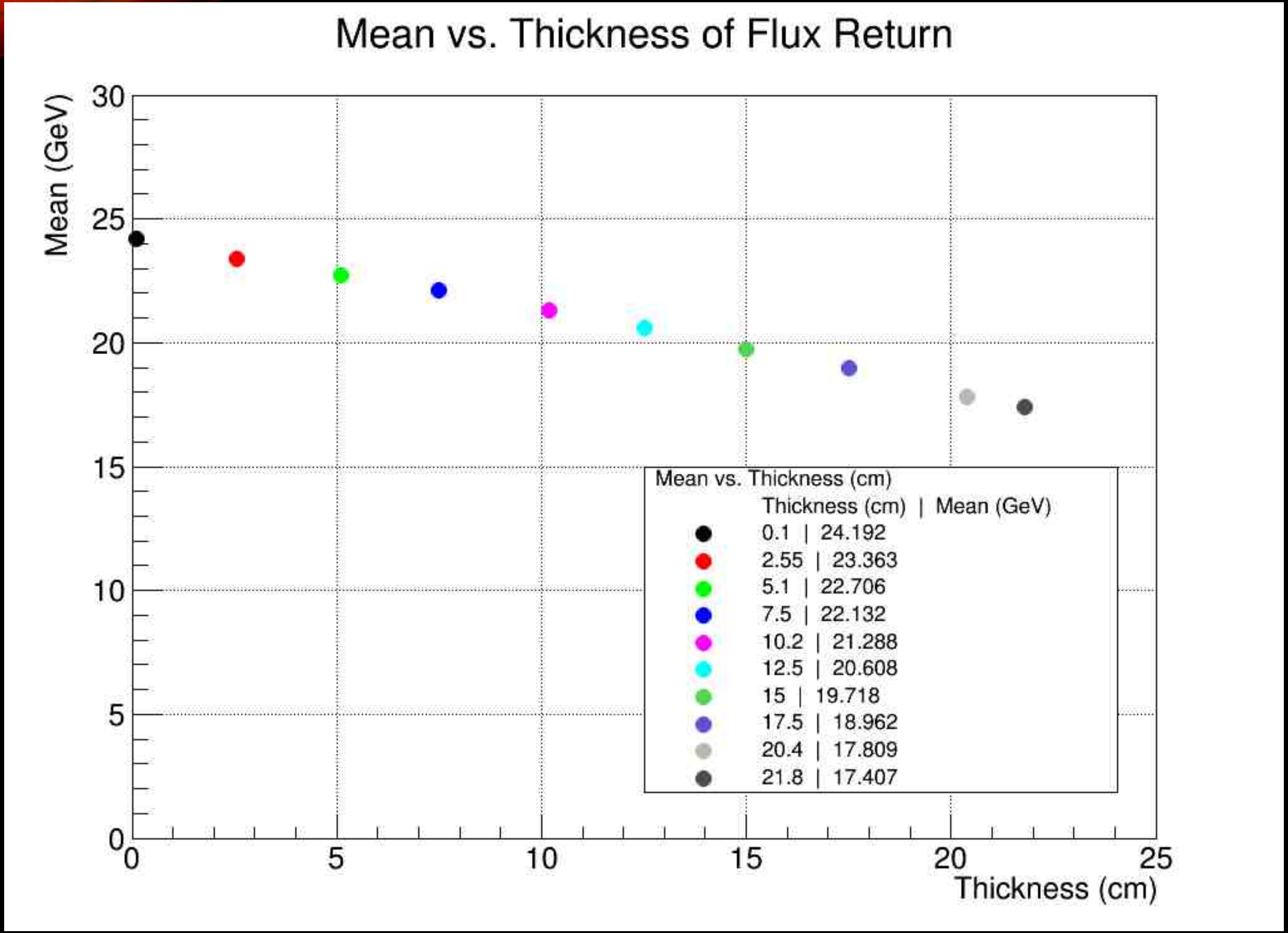

Number of Events vs. Reco Pi- Energy
Input: 30 GeV Pi-
Thickness: 12.5 cm
First Fit to Gaussian
Second Fit to Gaussian
Third Fit to Gaussian
Counts
0
500
1000
1500
2000
2500
0
5
10
15
20
25
30
35
40
Reco Pi- E(GeV)

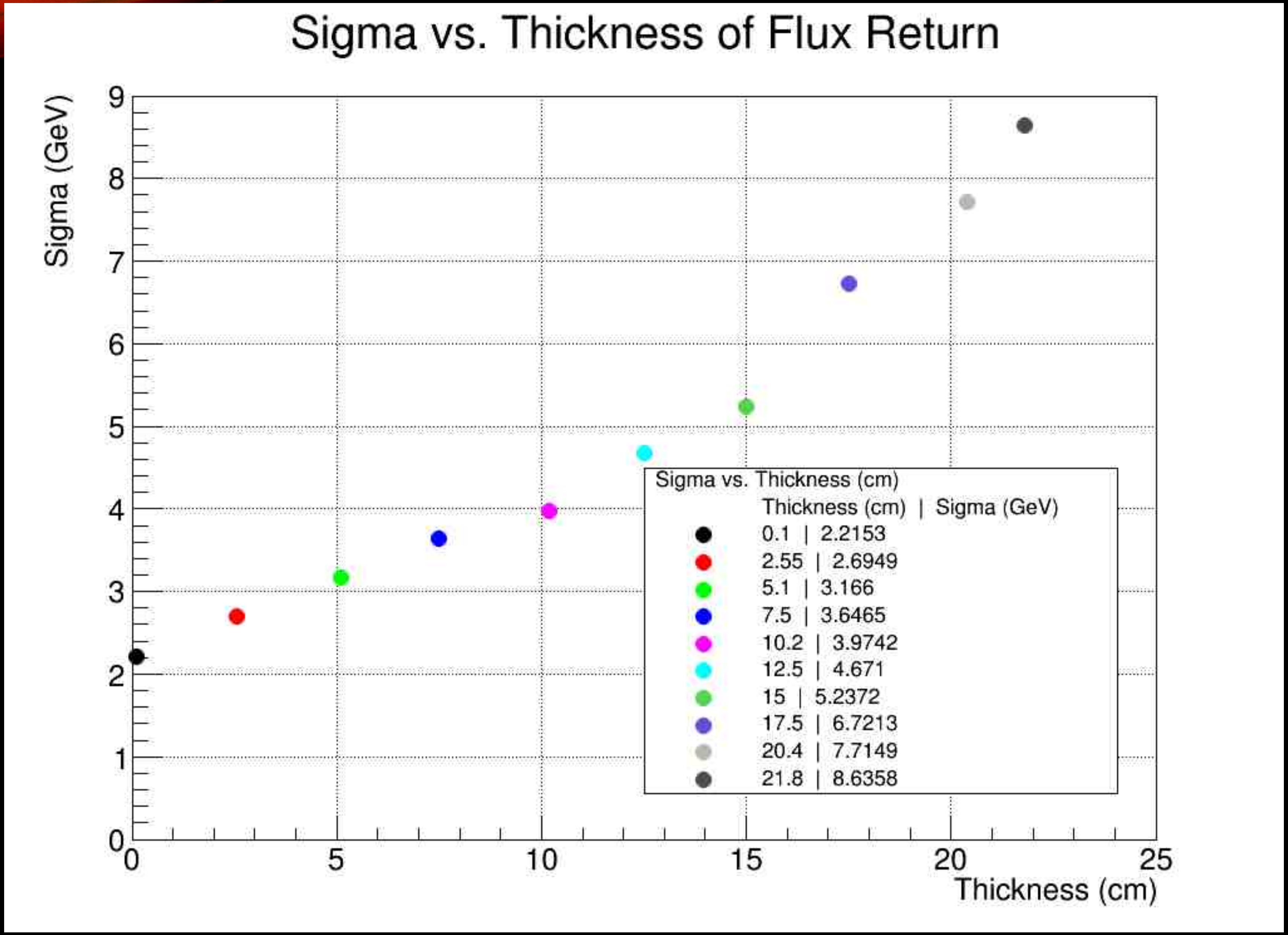

Number of Events vs. Reco Pi- Energy
Input: 30 GeV Pi-
Thickness: 15 cm
First Fit to Gaussian
Second Fit to Gaussian
Third Fit to Gaussian
Counts
2500
2000
1500
1000
500
0
0
5
10
15
20
25
30
35
40
Reco Pi- E(GeV)


Number of Events vs. Reco Pi- Energy
Input: 30 GeV Pi-
Thickness: 17.5 cm
First Fit to Gaussian
Second Fit to Gaussian
Third Fit to Gaussian
Counts
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
0
5
10
15
20
25
30
35
40
Reco Pi- E(GeV)

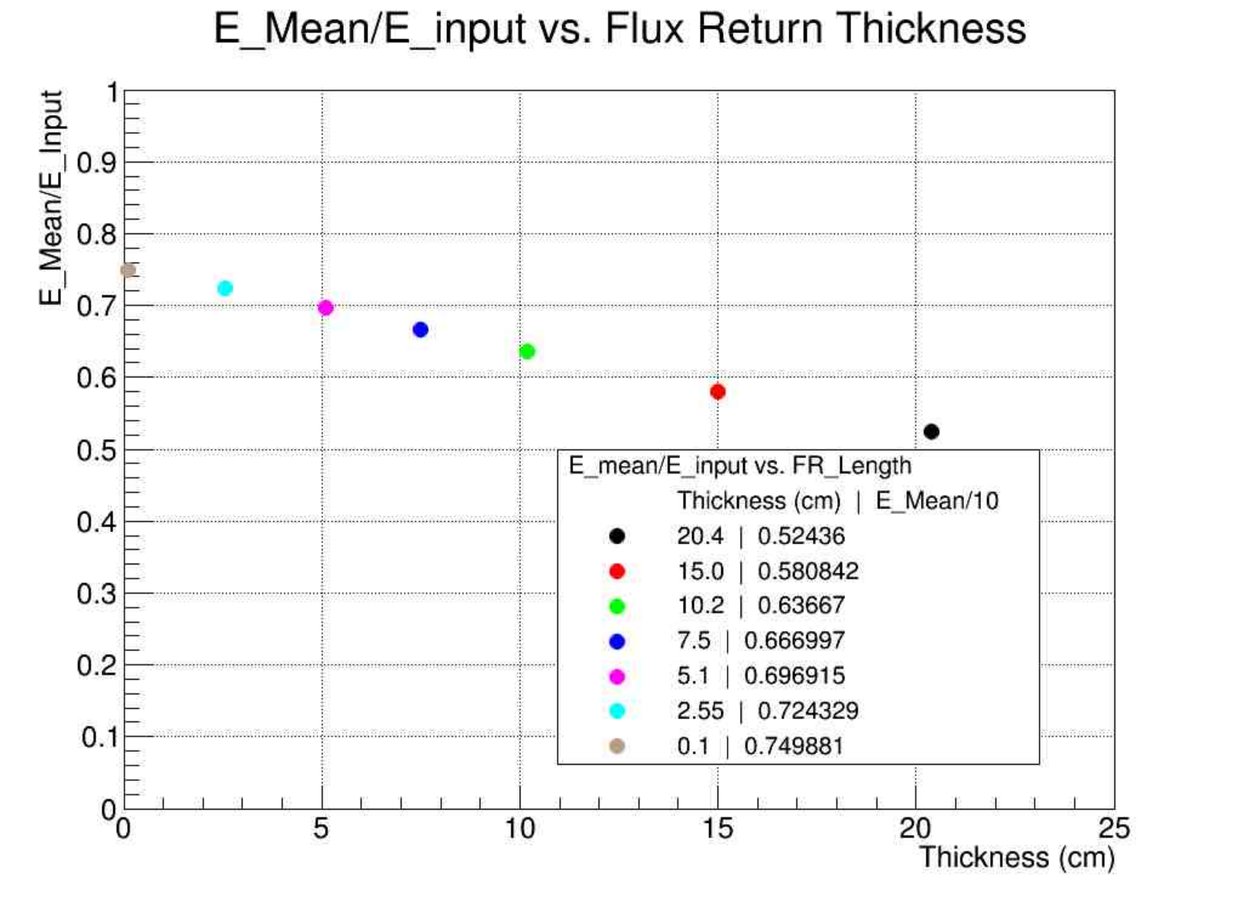


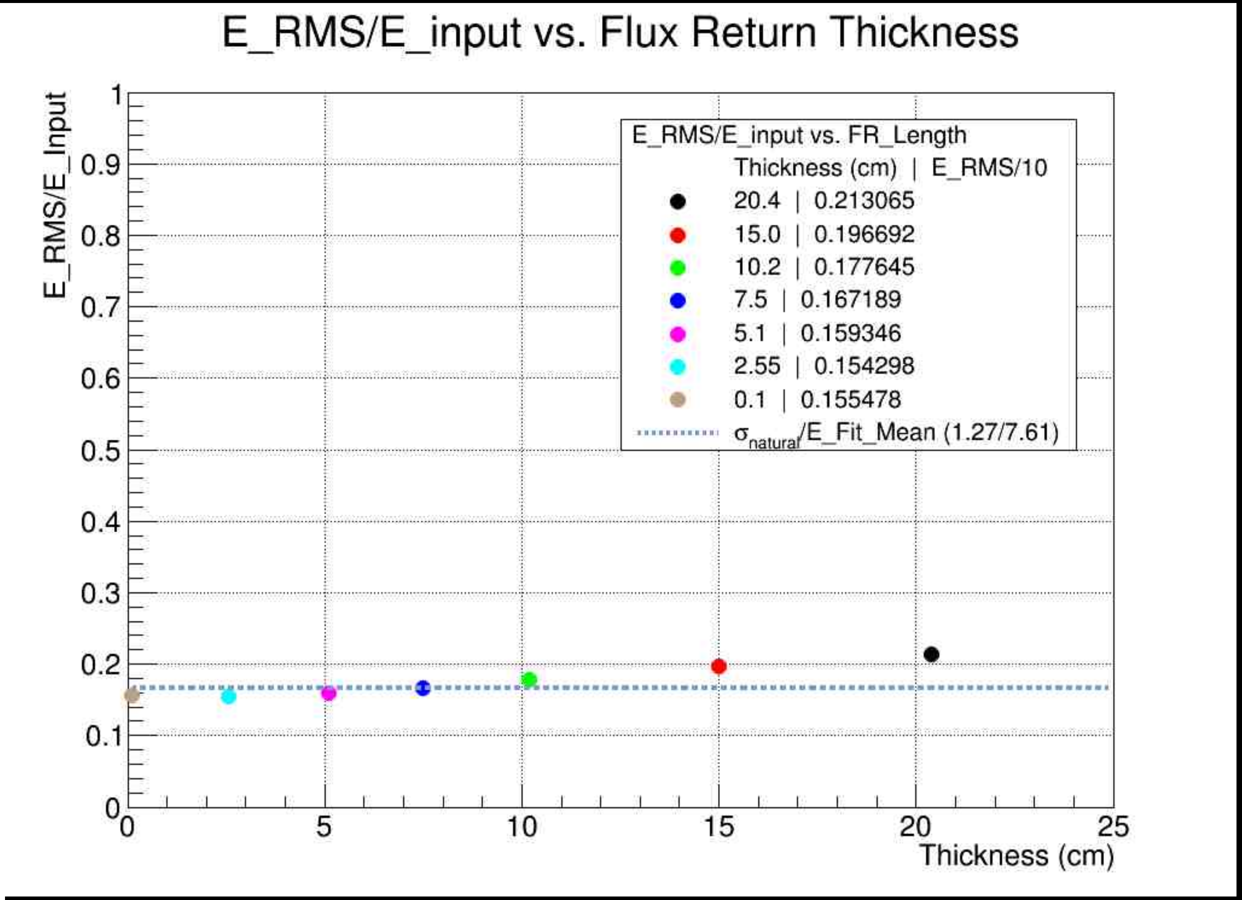
Number of Events vs. Reco Pi- Energy
Input: 30 GeV Pi-
Thickness: 21.8 cm
First Fit to Gaussian
Second Fit to Gaussian
Third Fit to Gaussian
Counts
0
200
400
600
800
1000
1200
1400
1600
1800
2000
0
5
10
15
20
25
30
35
40
Reco Pi- E(GeV)

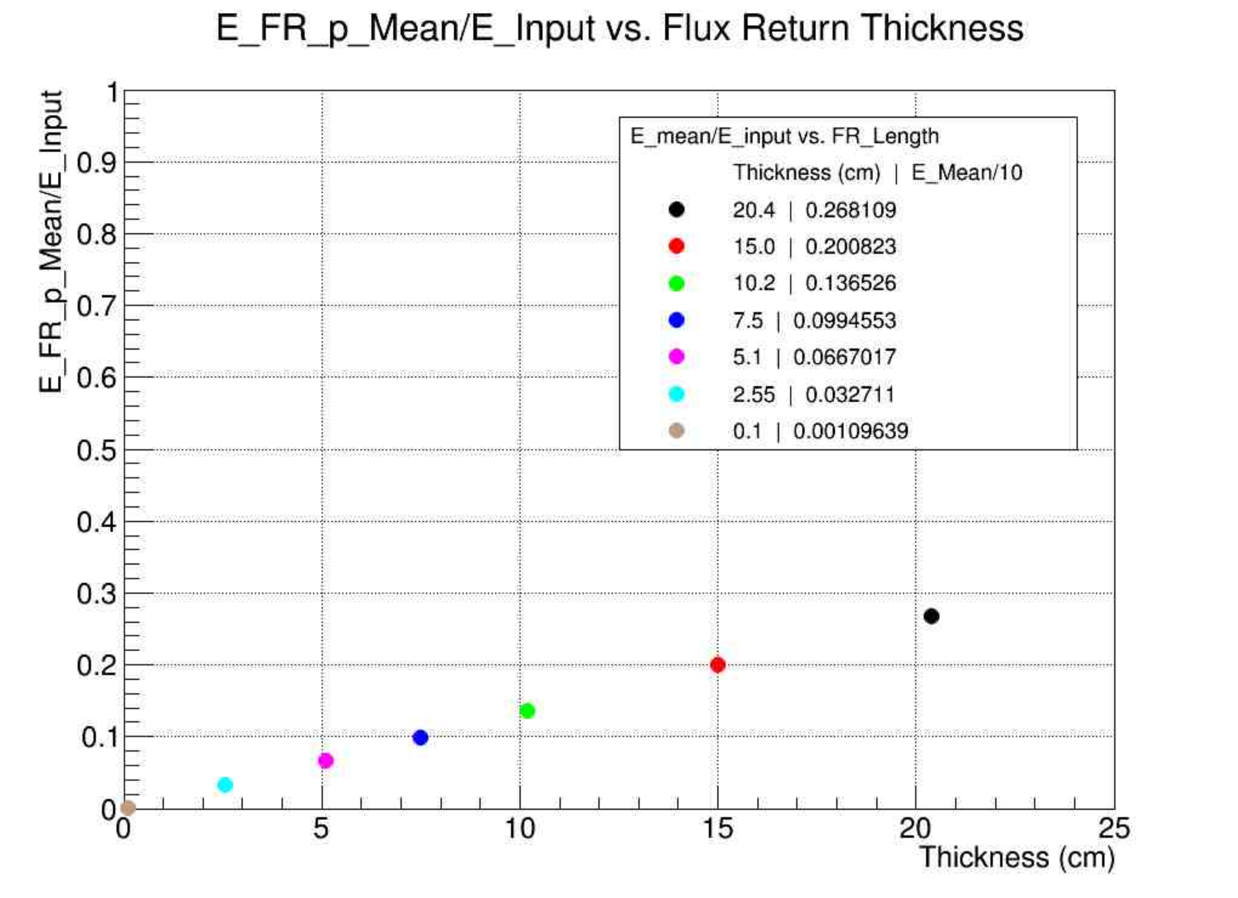

Mean vs. Thickness of Flux Return
Mean (GeV)
Thickness (cm)
0
5
10
15
20
25
30
Mean vs. Thickness (cm)
Thickness (cm) | Mean (GeV)
0.1 | 24.192
2.55 | 23.363
5.1 | 22.706
7.5 | 22.132
10.2 | 21.288
12.5 | 20.608
15 | 19.718
17.5 | 18.962
20.4 | 17.809
21.8 | 17.407

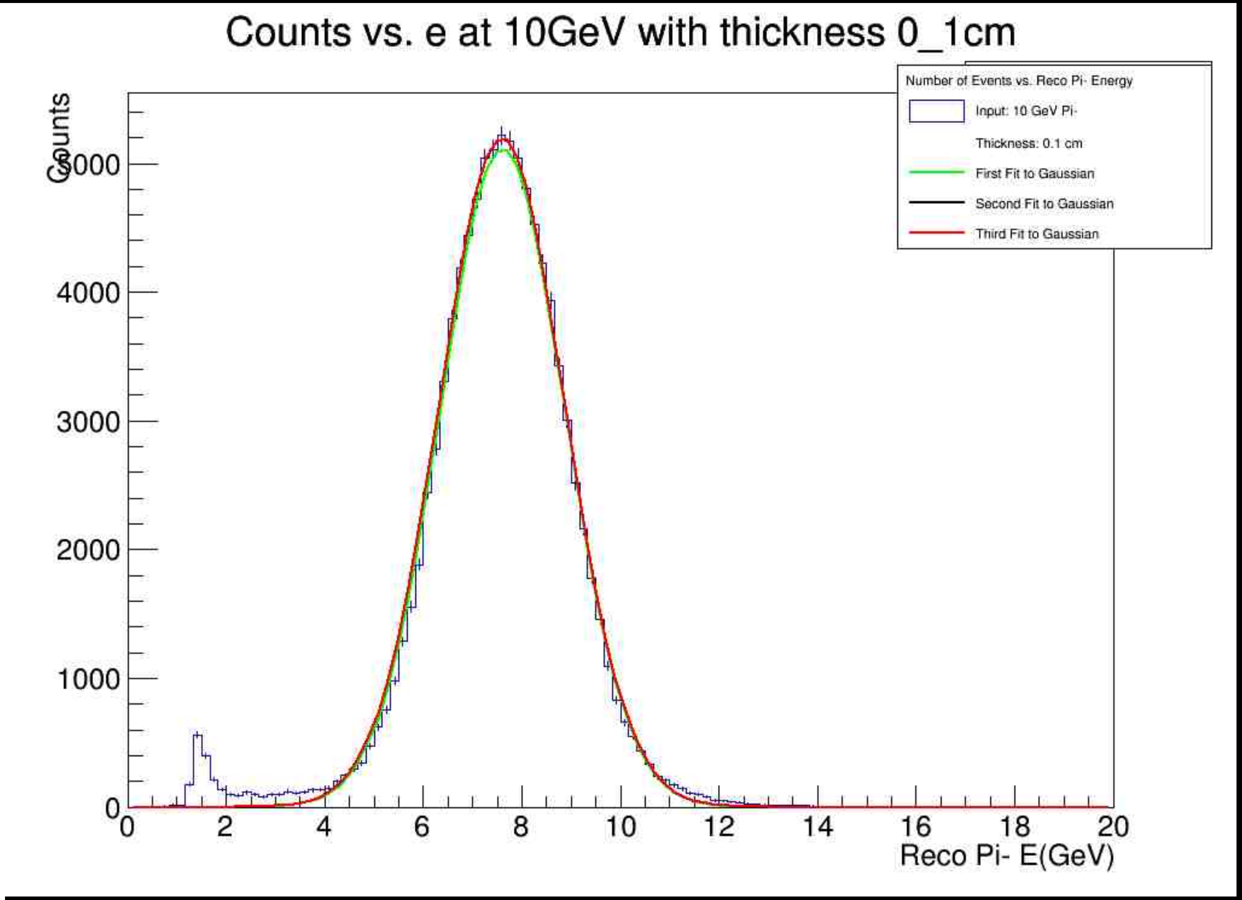

Sigma vs. Thickness of Flux Return
Sigma (GeV)
Thickness (cm)
0
1
2
3
4
5
6
7
8
9
0
5
10
15
20
25
Sigma vs. Thickness (cm)
Thickness (cm) | Sigma (GeV)
0.1 | 2.2153
2.55 | 2.6949
5.1 | 3.166
7.5 | 3.6465
10.2 | 3.9742
12.5 | 4.671
15 | 5.2372
17.5 | 6.7213
20.4 | 7.7149
21.8 | 8.6358

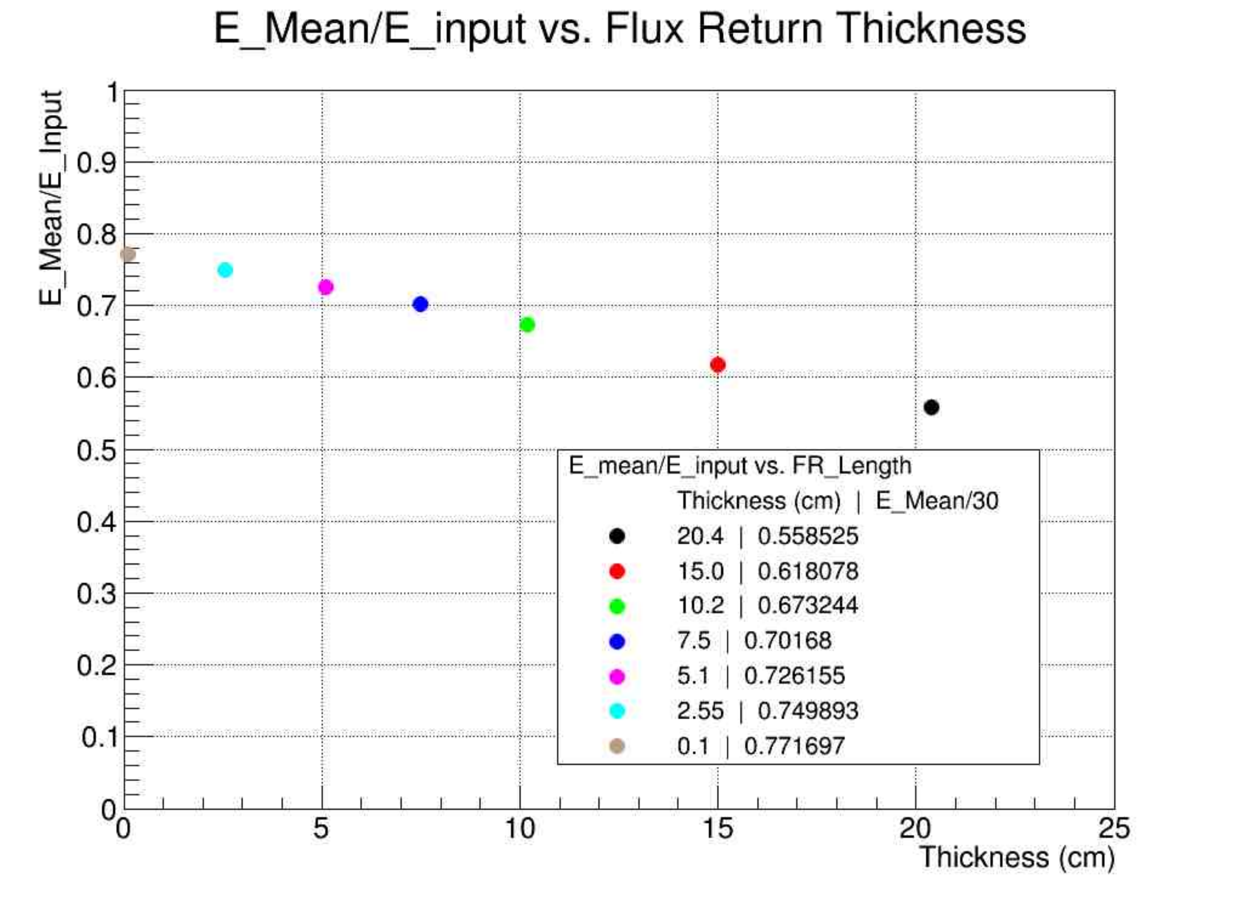
EXTRA E/E_INPUT PLOTS

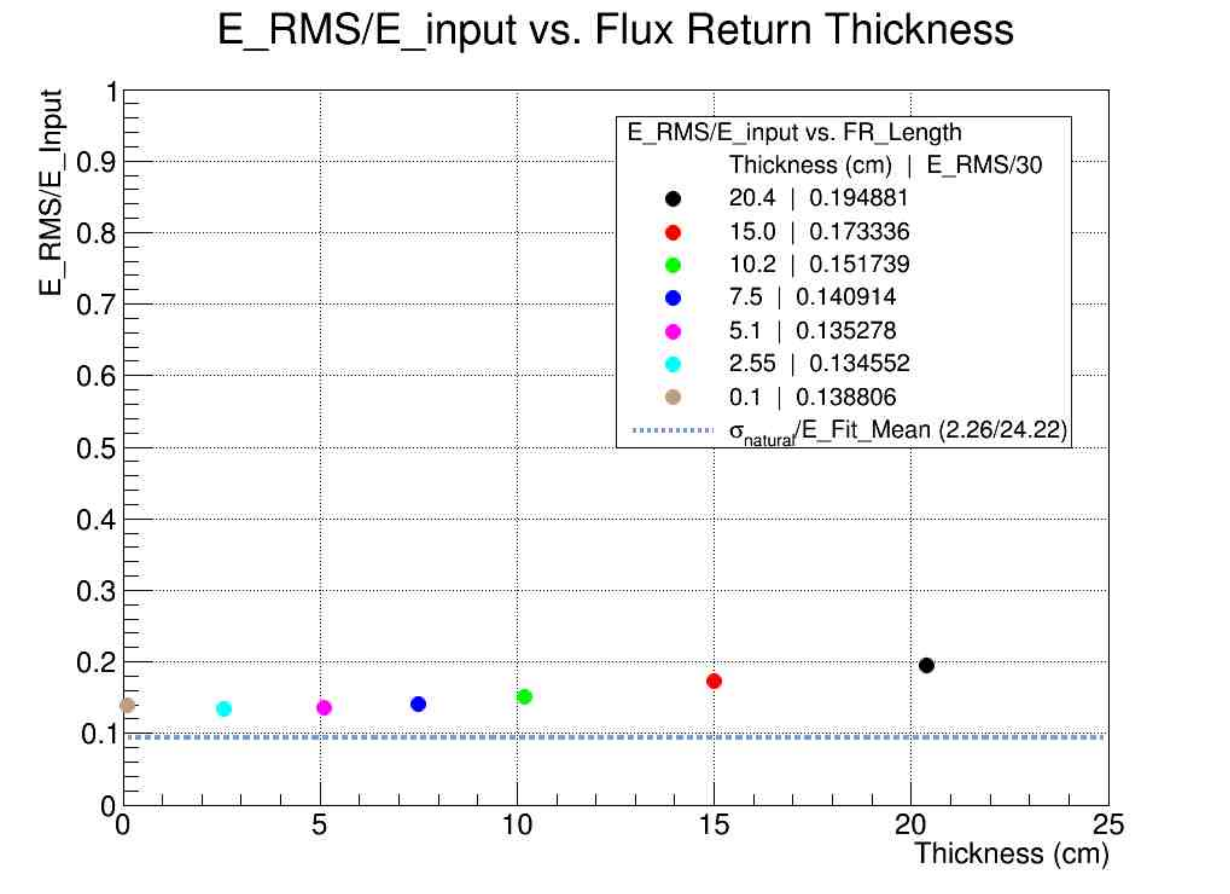

E_Mean/E_input vs. Flux Return Thickness
E_Mean/E_Input
Thickness (cm)
E_mean/E_input vs. FR_Length
Thickness (cm) | E_Mean/10
20.4 | 0.52436
15.0 | 0.580842
10.2 | 0.63667
7.5 | 0.666997
5.1 | 0.696915
2.55 | 0.724329
0.1 | 0.749881

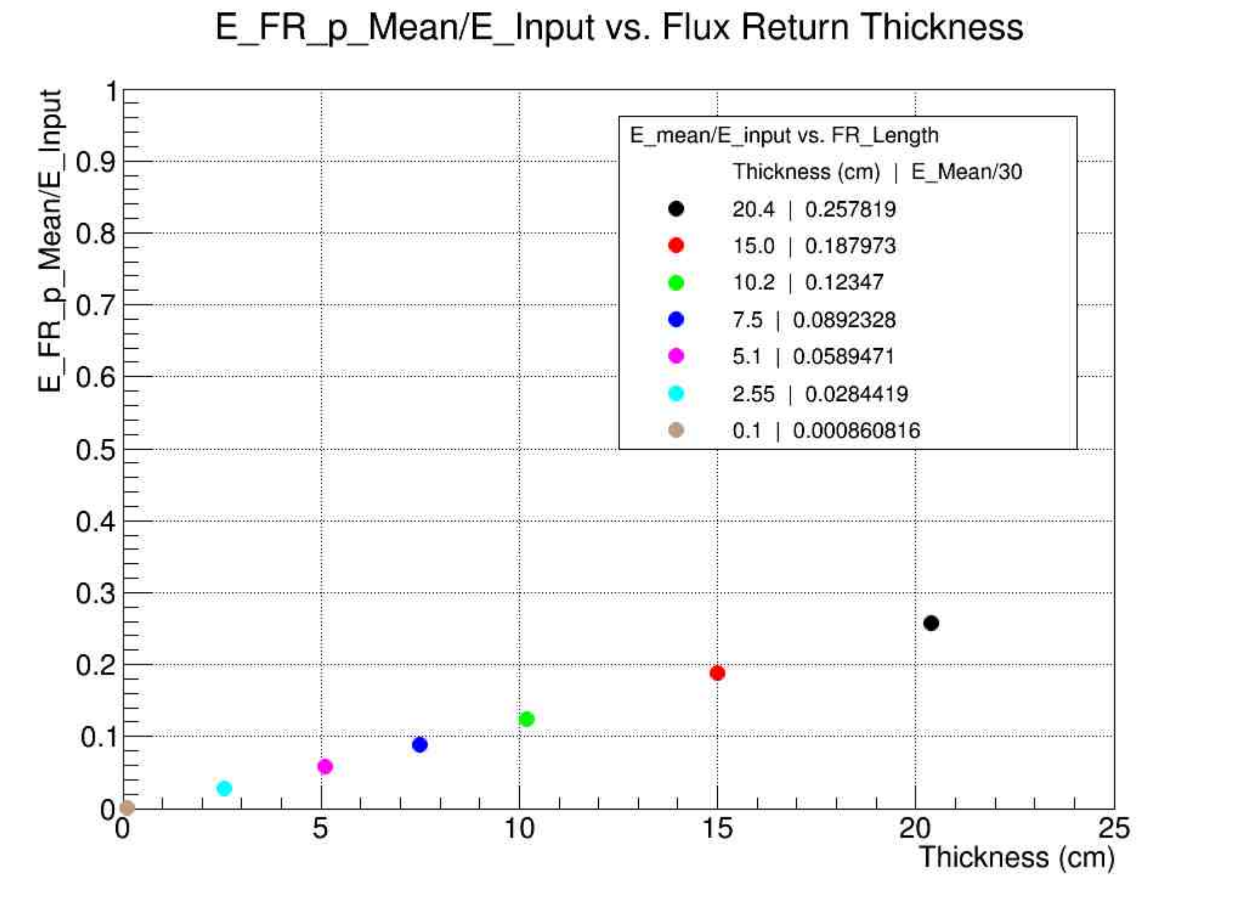

E_RMS/E_input vs. Flux Return Thickness
E_RMS/E_Input
Thickness (cm)
E_RMS/E_input vs. FR_Length
Thickness (cm) | E_RMS/10
20.4 | 0.213065
15.0 | 0.196692
10.2 | 0.177645
7.5 | 0.167189
5.1 | 0.159346
2.55 | 0.154298
0.1 | 0.155478
$\sigma_{natural}$/E_Fit_Mean (1.27/7.61)

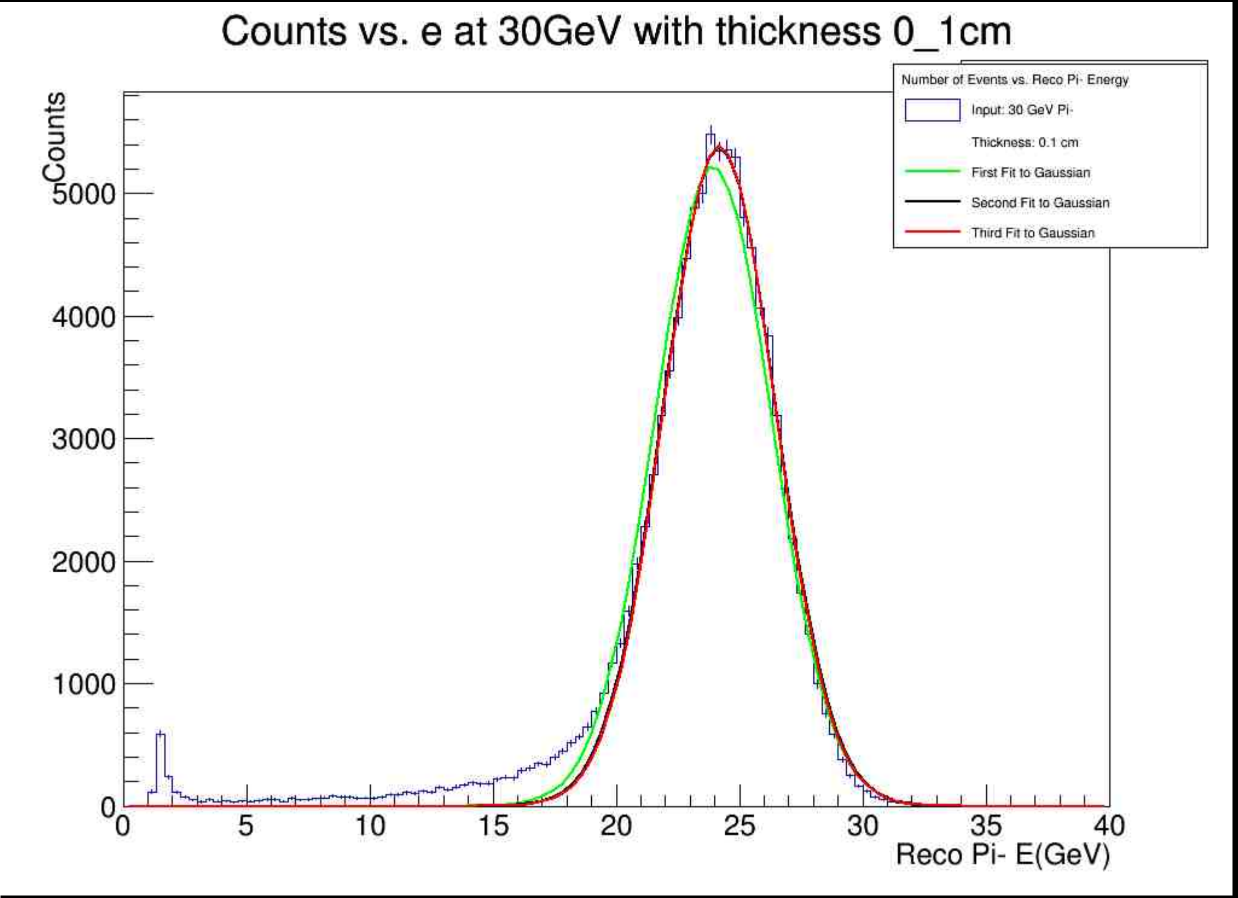

E_FR_p_Mean/E_Input vs. Flux Return Thickness
E_mean/E_input vs. FR_Length
Thickness (cm) | E_Mean/10
20.4 | 0.268109
15.0 | 0.200823
10.2 | 0.136526
7.5 | 0.0994553
5.1 | 0.0667017
2.55 | 0.032711
0.1 | 0.00109639
E_FR_p_Mean/E_Input
Thickness (cm)

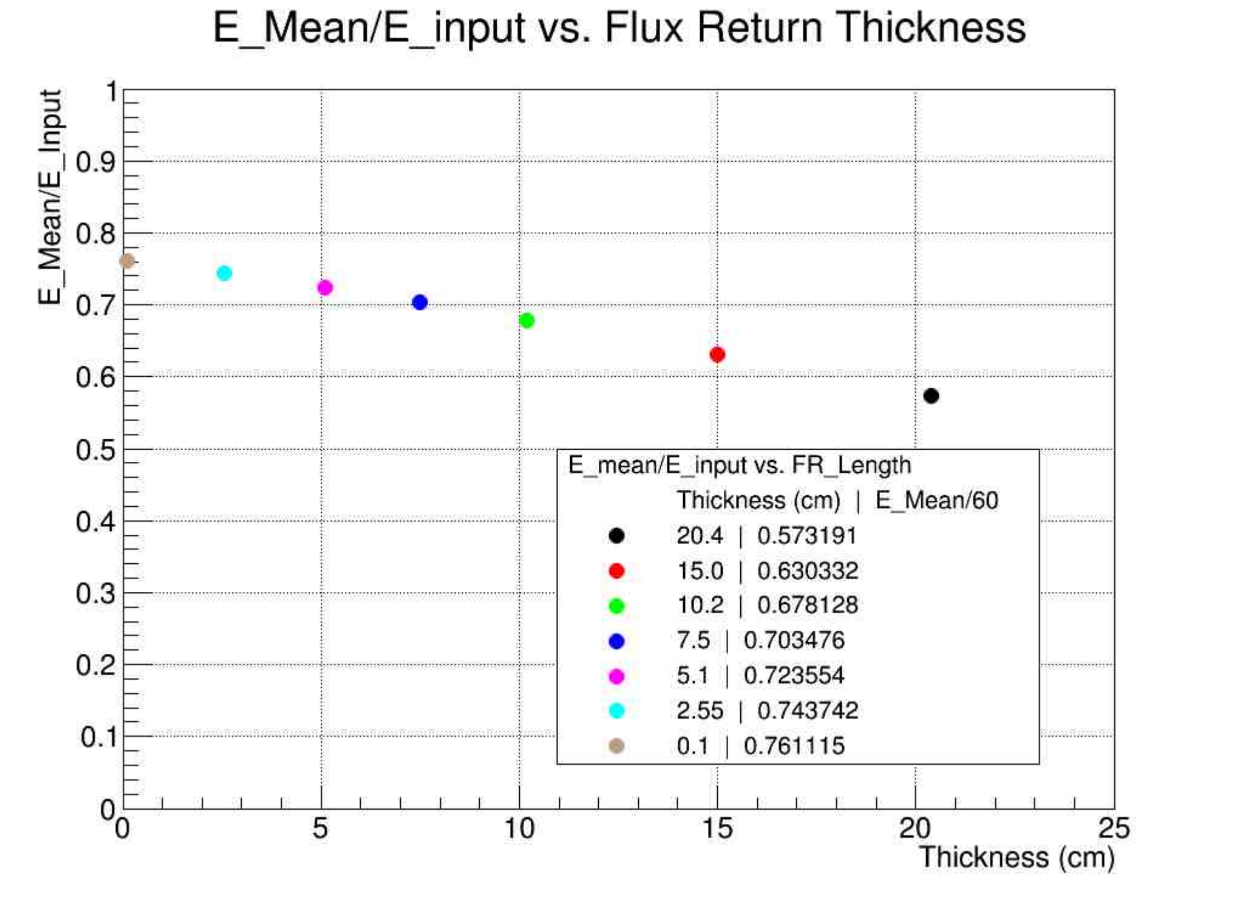

Counts vs. e at 10GeV with thickness 0_1cm
Number of Events vs. Reco Pi- Energy
Input: 10 GeV Pi-
Thickness: 0.1 cm
First Fit to Gaussian
Second Fit to Gaussian
Third Fit to Gaussian
Counts
Reco Pi- E(GeV)

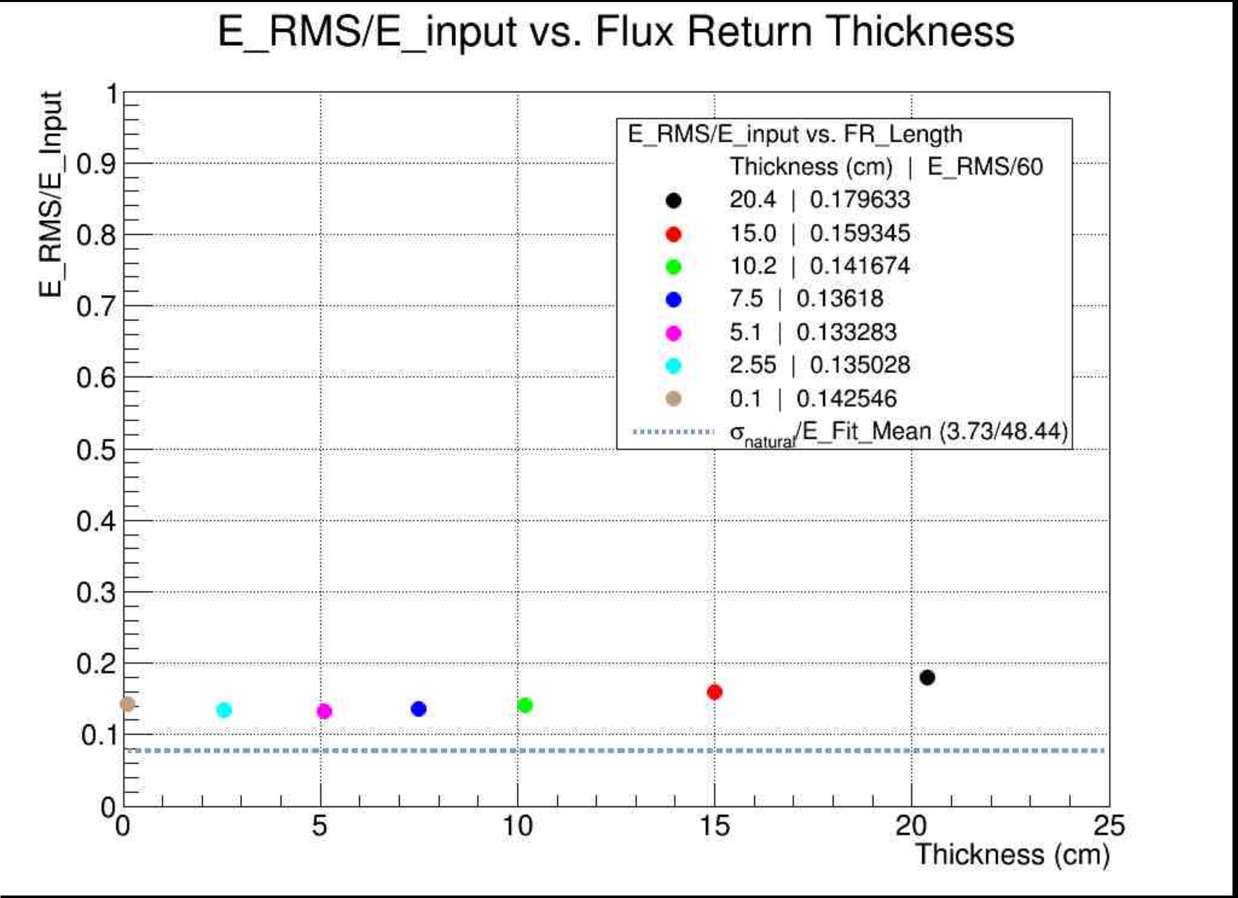

E_Mean/E_input vs. Flux Return Thickness
E_Mean/E_Input
Thickness (cm)
E_mean/E_input vs. FR_Length
Thickness (cm) | E_Mean/30
20.4 | 0.558525
15.0 | 0.618078
10.2 | 0.673244
7.5 | 0.70168
5.1 | 0.726155
2.55 | 0.749893
0.1 | 0.771697

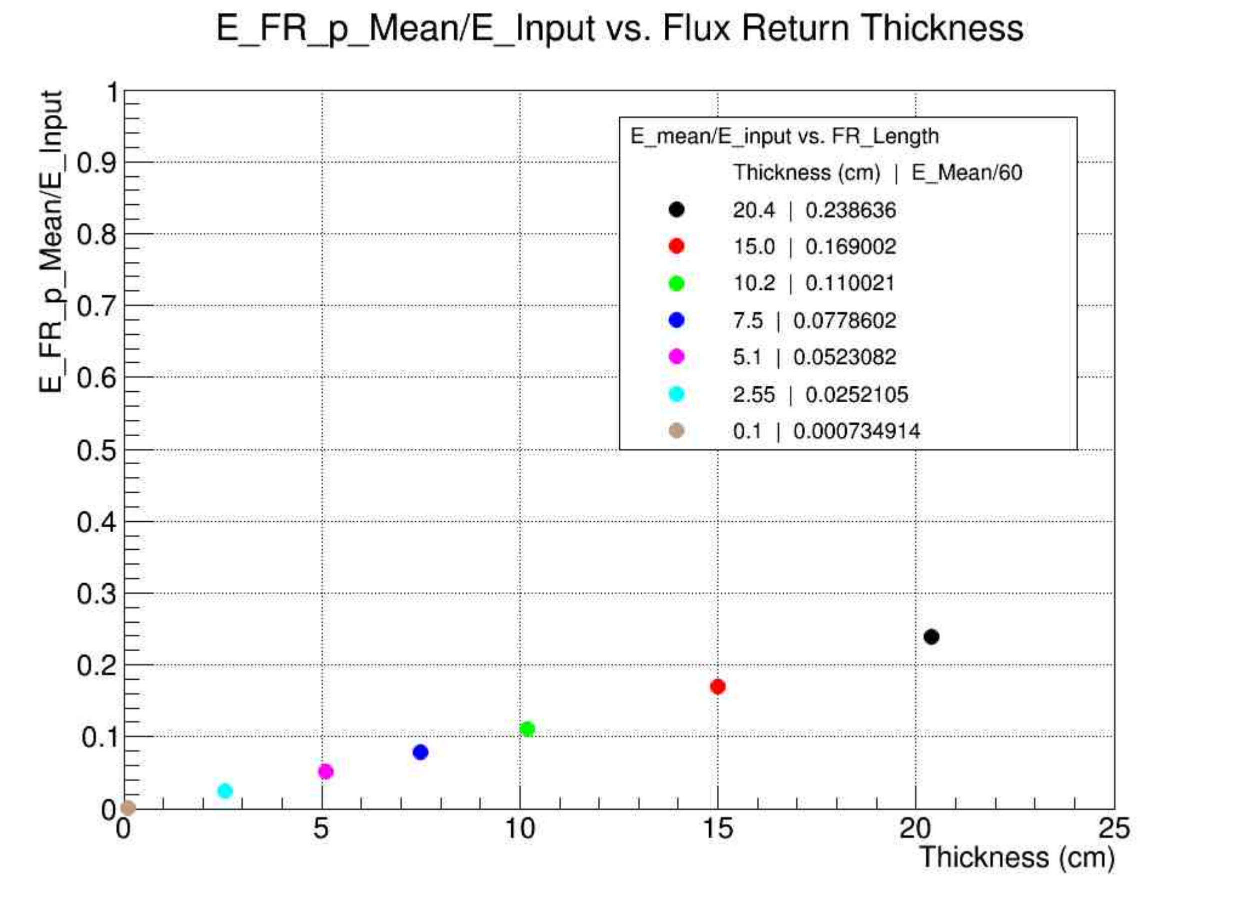

E_RMS/E_input vs. Flux Return Thickness
E_RMS/E_Input
Thickness (cm)
E_RMS/E_input vs. FR_Length
Thickness (cm) | E_RMS/30
20.4 | 0.194881
15.0 | 0.173336
10.2 | 0.151739
7.5 | 0.140914
5.1 | 0.135278
2.55 | 0.134552
0.1 | 0.138806
σnatural/E_Fit_Mean (2.26/24.22)

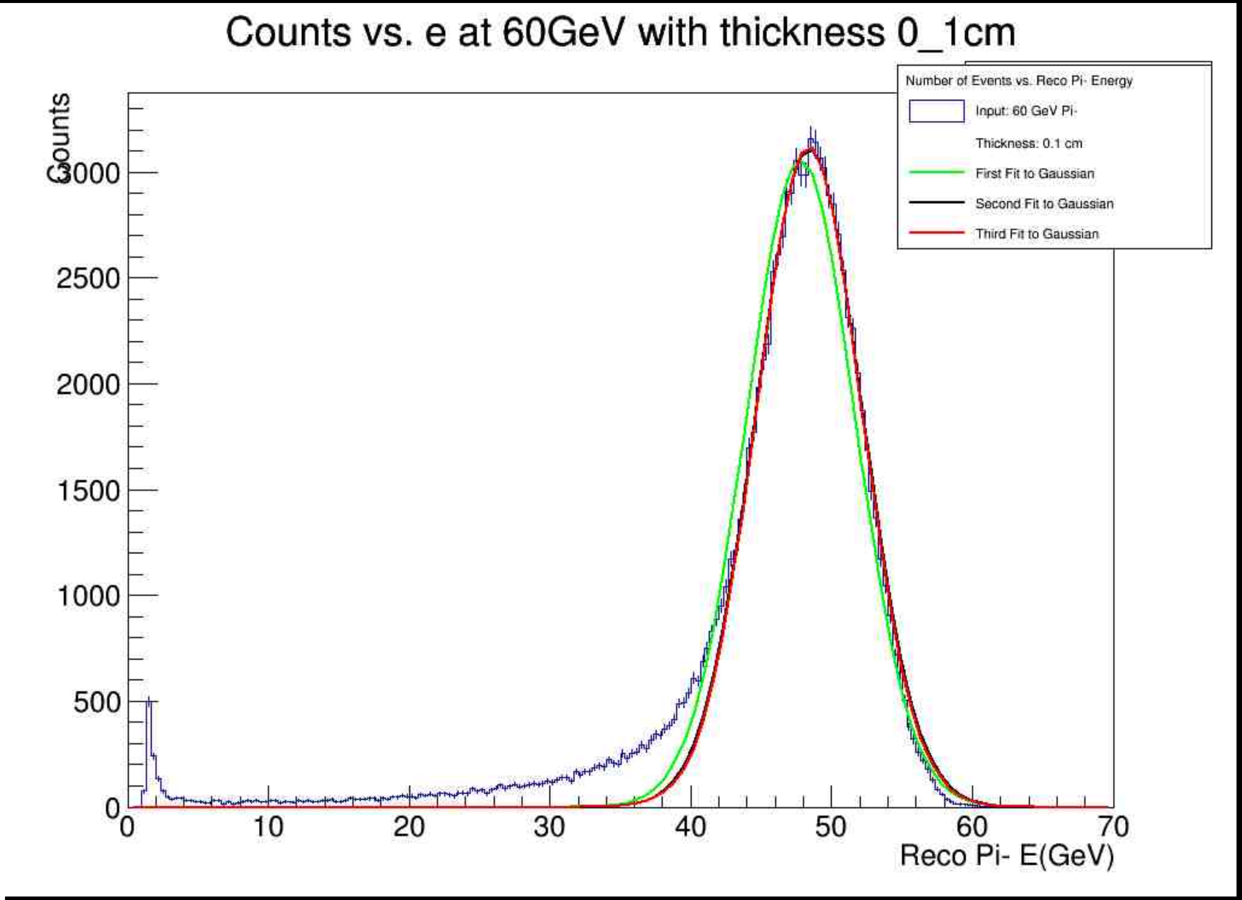

E_FR_p_Mean/E_Input vs. Flux Return Thickness
E_FR_p_Mean/E_Input
Thickness (cm)
E_mean/E_input vs. FR_Length
Thickness (cm) | E_Mean/30
20.4 | 0.257819
15.0 | 0.187973
10.2 | 0.12347
7.5 | 0.0892328
5.1 | 0.0589471
2.55 | 0.0284419
0.1 | 0.000860816

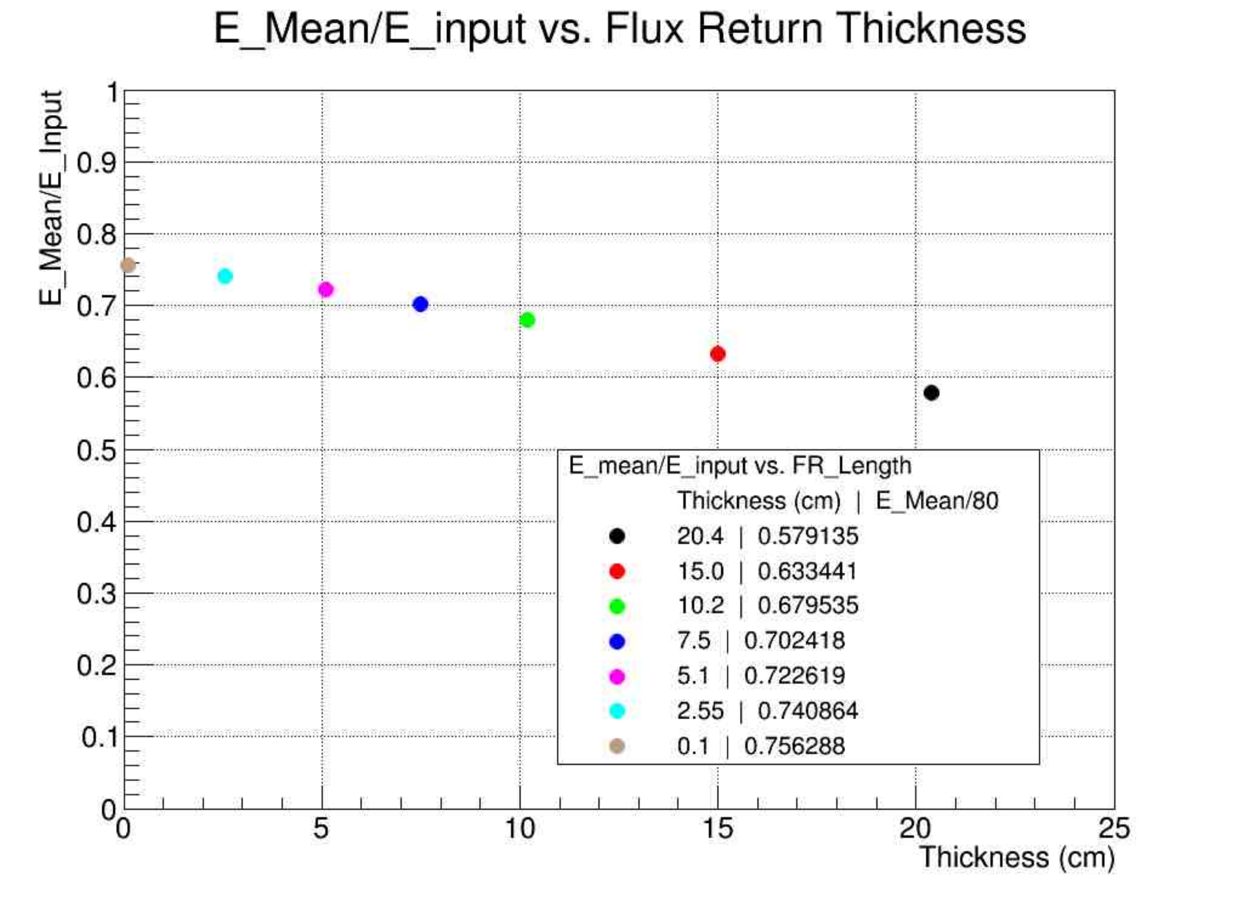

Counts vs. e at 30GeV with thickness 0_1cm
Counts
Reco Pi- E(GeV)
Number of Events vs. Reco Pi- Energy
Input: 30 GeV Pi-
Thickness: 0.1 cm
First Fit to Gaussian
Second Fit to Gaussian
Third Fit to Gaussian

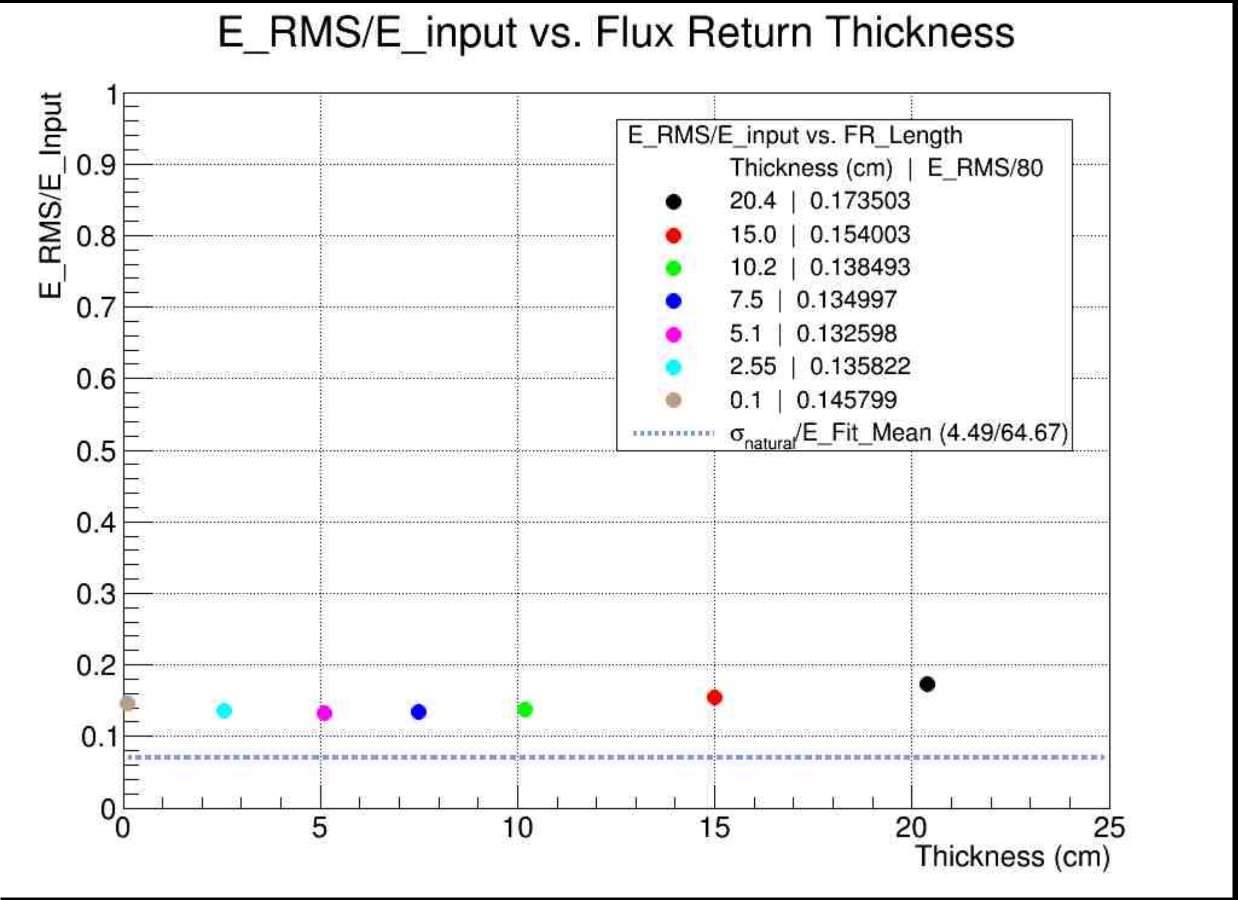

E_Mean/E_input vs. Flux Return Thickness
E_Mean/E_Input
Thickness (cm)
E_mean/E_input vs. FR_Length
Thickness (cm) | E_Mean/60
20.4 | 0.573191
15.0 | 0.630332
10.2 | 0.678128
7.5 | 0.703476
5.1 | 0.723554
2.55 | 0.743742
0.1 | 0.761115

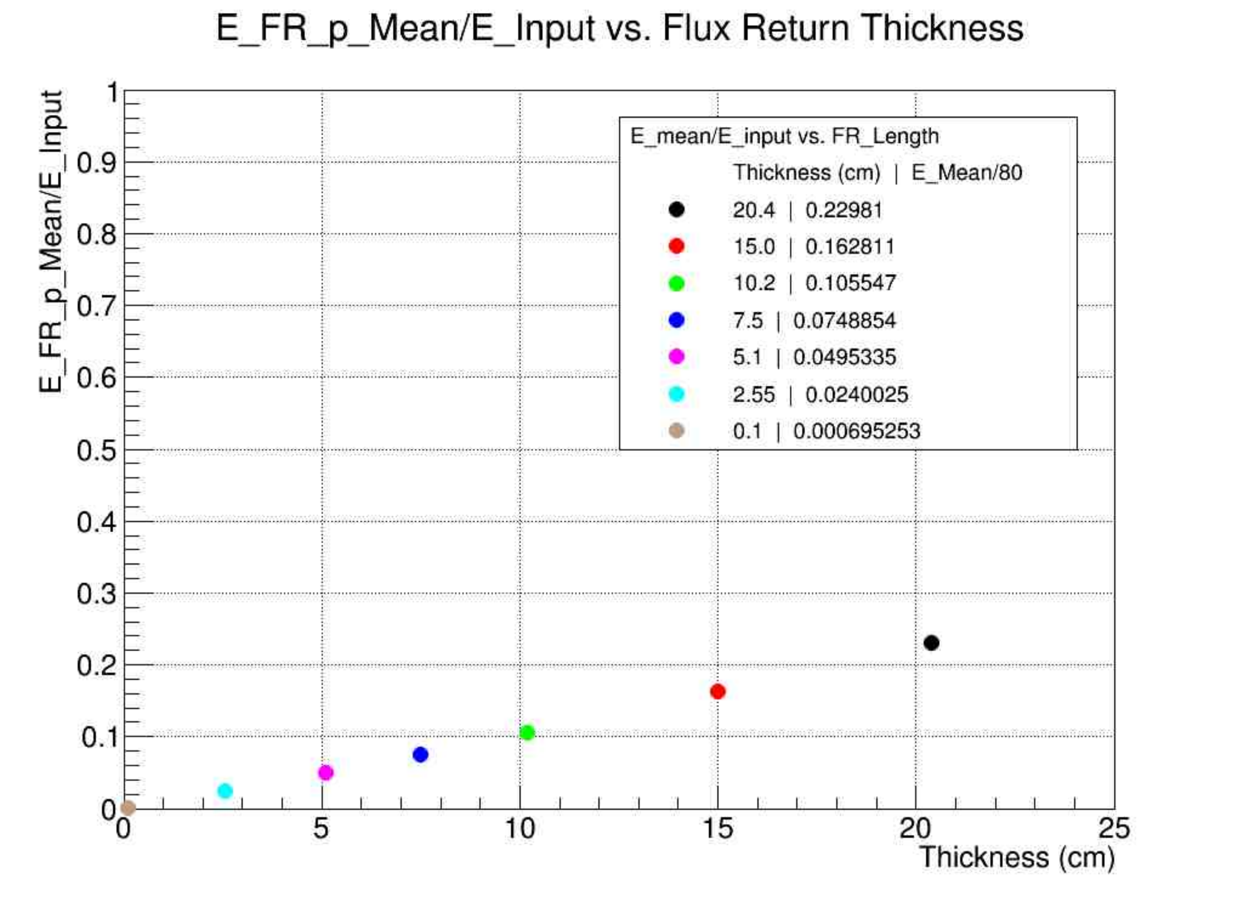

E_RMS/E_input vs. Flux Return Thickness
E_RMS/E_Input
Thickness (cm)
E_RMS/E_input vs. FR_Length
Thickness (cm) | E_RMS/60
20.4 | 0.179633
15.0 | 0.159345
10.2 | 0.141674
7.5 | 0.13618
5.1 | 0.133283
2.55 | 0.135028
0.1 | 0.142546
σ_natural/E_Fit_Mean (3.73/48.44)

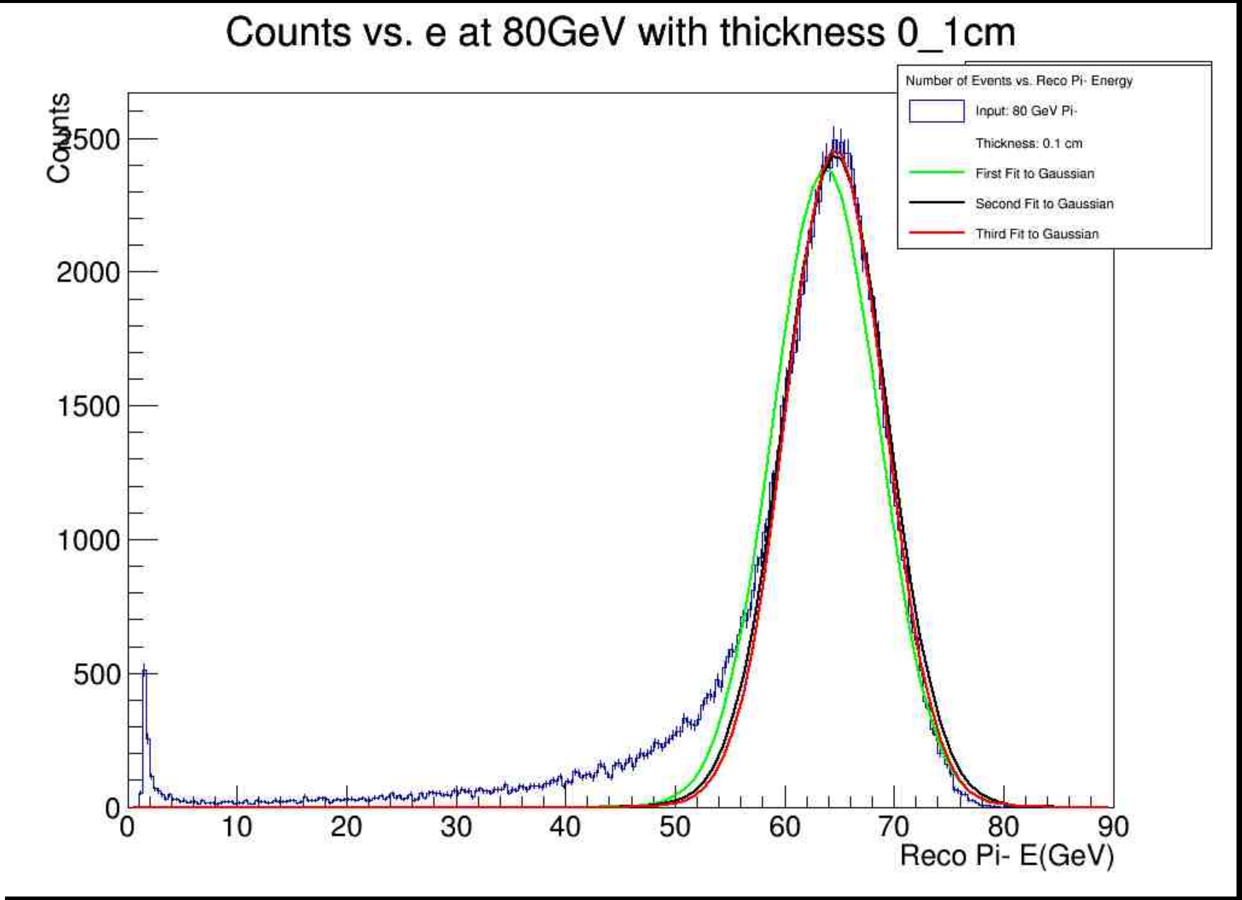

E_FR_p_Mean/E_Input vs. Flux Return Thickness
E_FR_p_Mean/E_Input
Thickness (cm)
E_mean/E_input vs. FR_Length
Thickness (cm) | E_Mean/60
20.4 | 0.238636
15.0 | 0.169002
10.2 | 0.110021
7.5 | 0.0778602
5.1 | 0.0523082
2.55 | 0.0252105
0.1 | 0.000734914

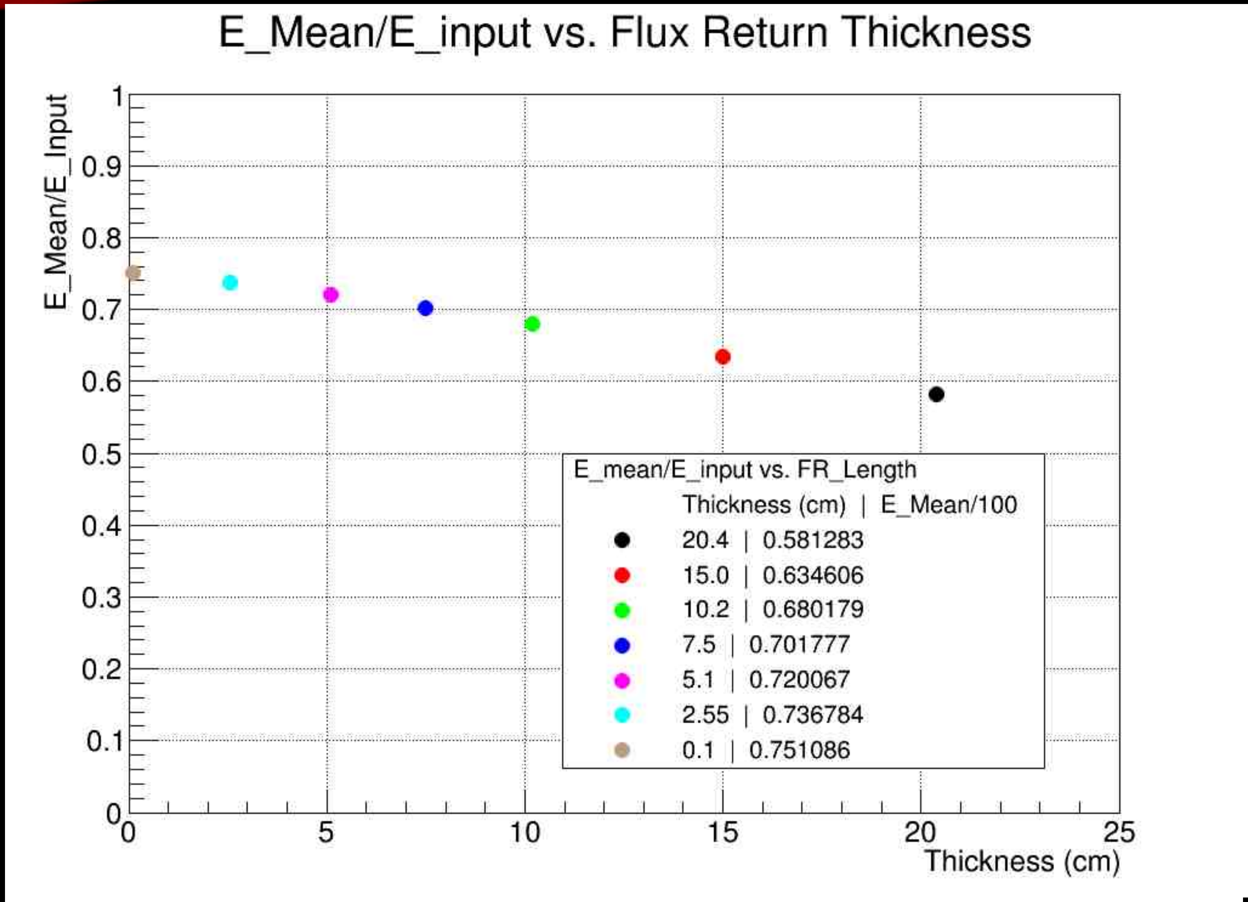

Counts vs. e at 60GeV with thickness 0_1cm
Counts
Reco Pi- E(GeV)
Number of Events vs. Reco Pi- Energy
Input: 60 GeV Pi-
Thickness: 0.1 cm
First Fit to Gaussian
Second Fit to Gaussian
Third Fit to Gaussian

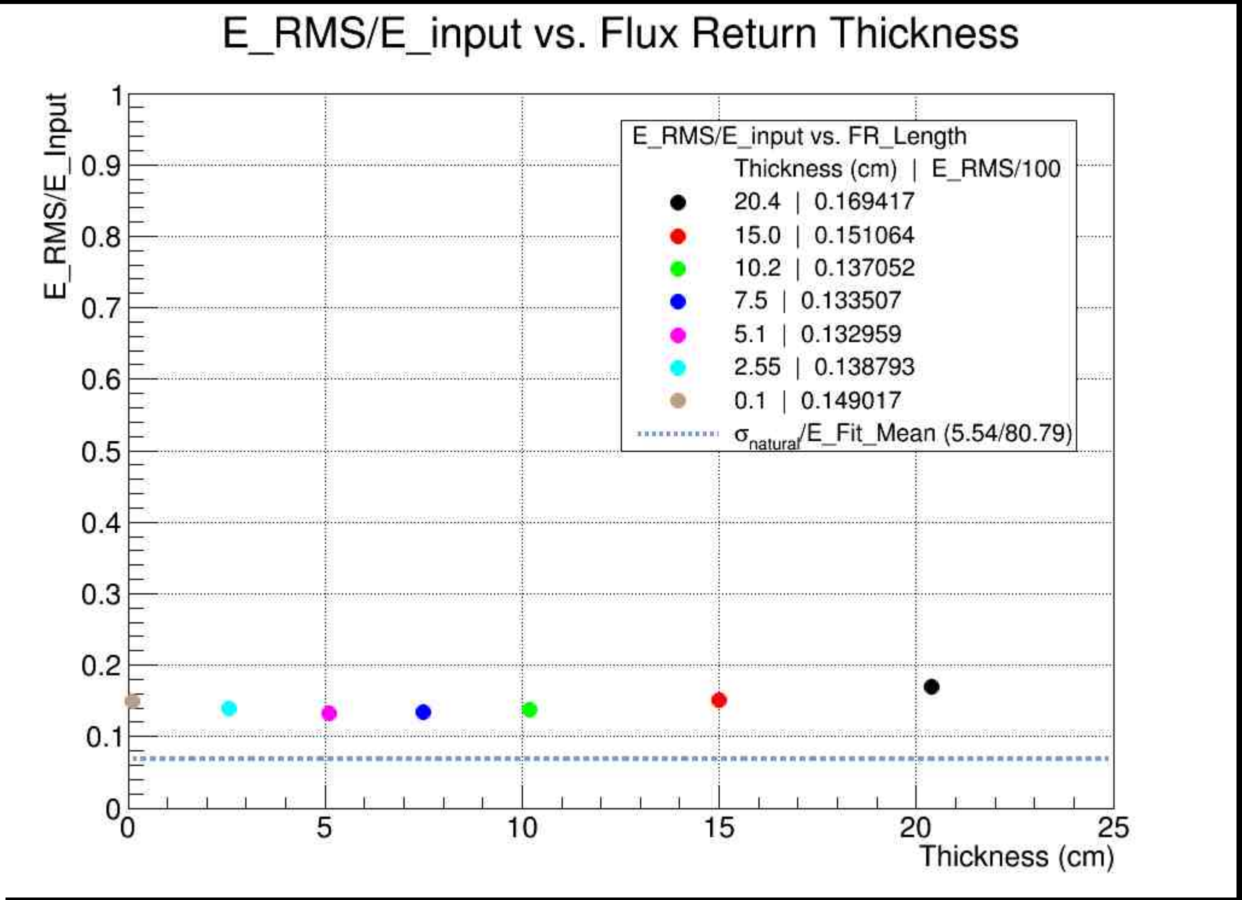

E_Mean/E_input vs. Flux Return Thickness
E_Mean/E_Input
Thickness (cm)
E_mean/E_input vs. FR_Length
Thickness (cm) | E_Mean/80
20.4 | 0.579135
15.0 | 0.633441
10.2 | 0.679535
7.5 | 0.702418
5.1 | 0.722619
2.55 | 0.740864
0.1 | 0.756288

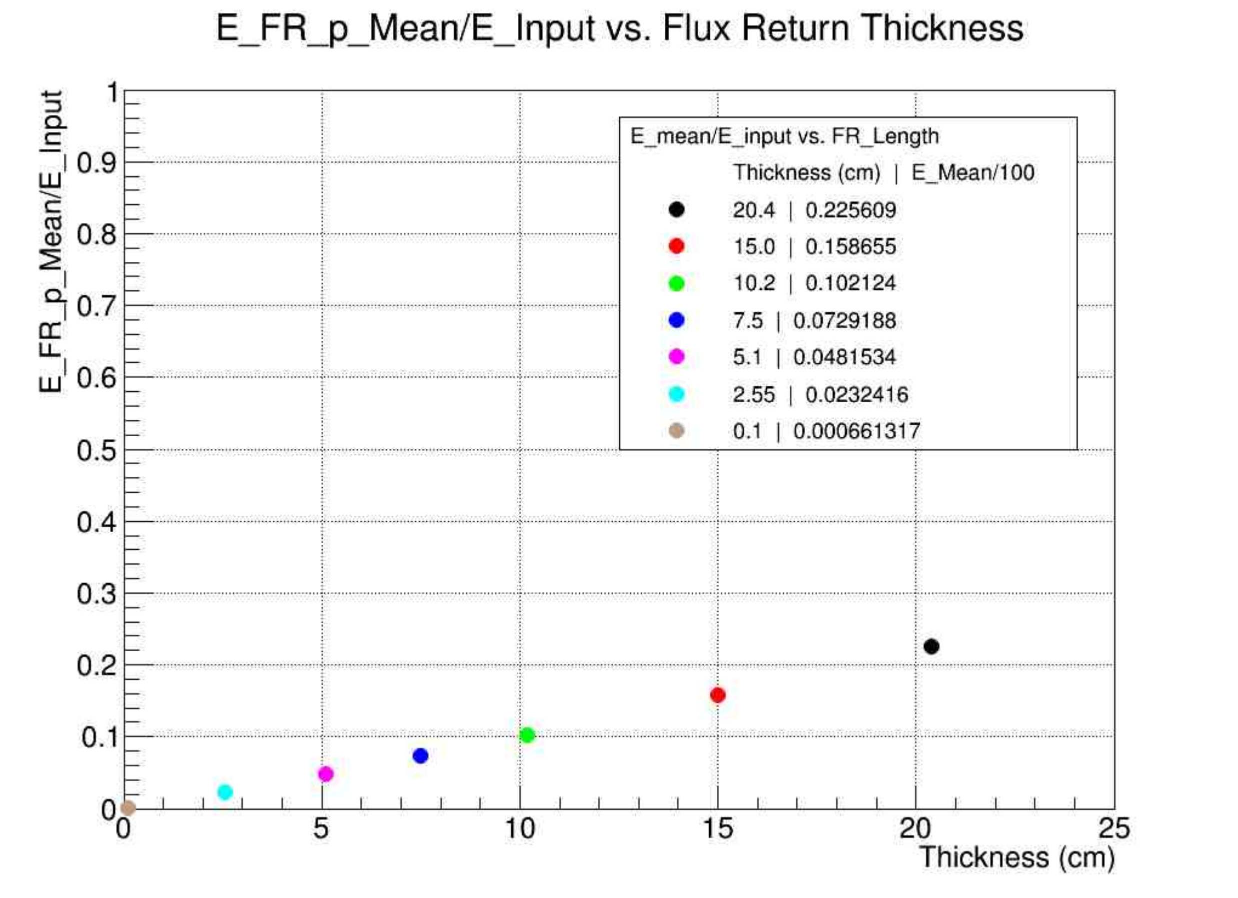

E_RMS/E_input vs. Flux Return Thickness
E_RMS/E_Input
Thickness (cm)
E_RMS/E_input vs. FR_Length
Thickness (cm) | E_RMS/80
20.4 | 0.173503
15.0 | 0.154003
10.2 | 0.138493
7.5 | 0.134997
5.1 | 0.132598
2.55 | 0.135822
0.1 | 0.145799
$\sigma_{natural}$/E_Fit_Mean (4.49/64.67)

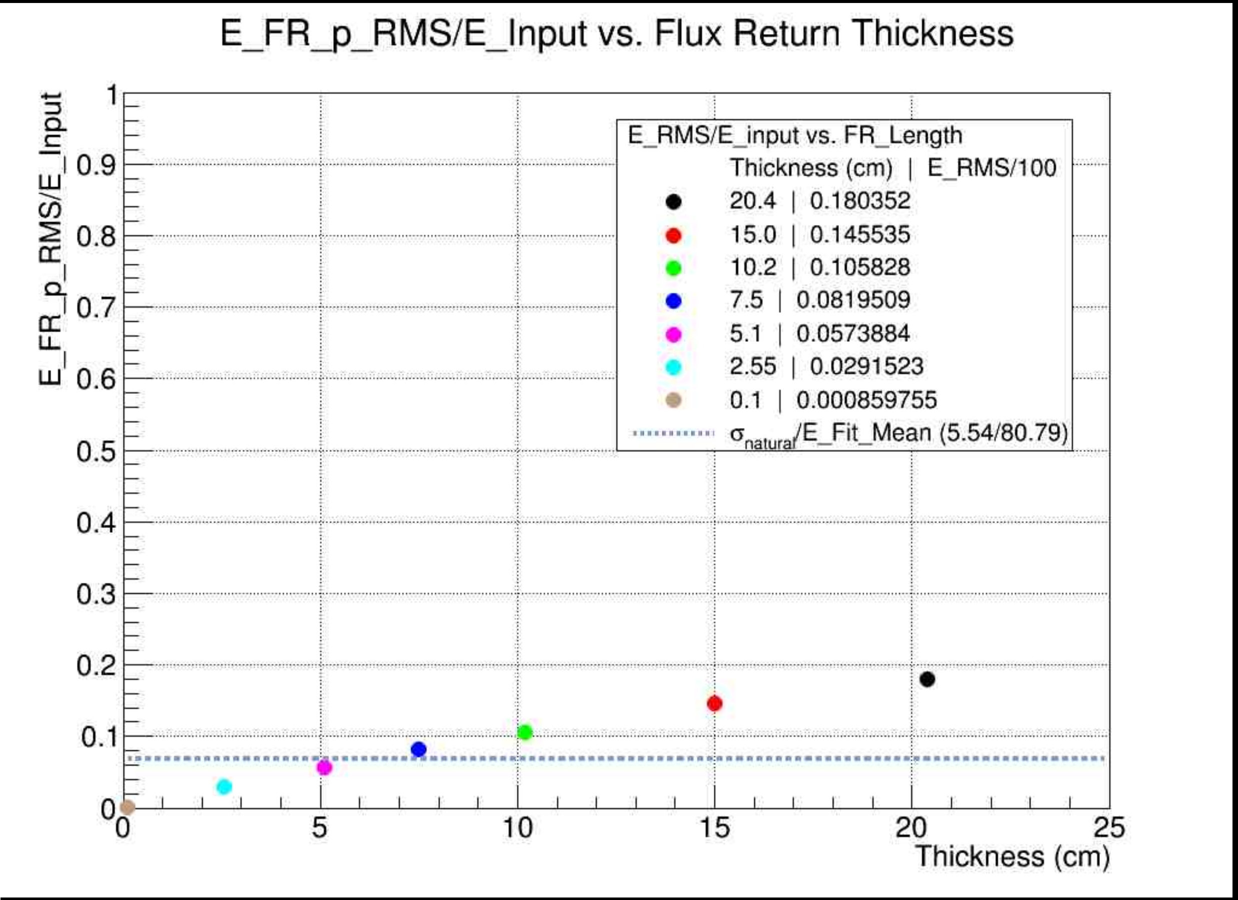

E_FR_p_Mean/E_Input vs. Flux Return Thickness
E_mean/E_input vs. FR_Length
Thickness (cm) | E_Mean/80
20.4 | 0.22981
15.0 | 0.162811
10.2 | 0.105547
7.5 | 0.0748854
5.1 | 0.0495335
2.55 | 0.0240025
0.1 | 0.000695253
E_FR_p_Mean/E_Input
Thickness (cm)

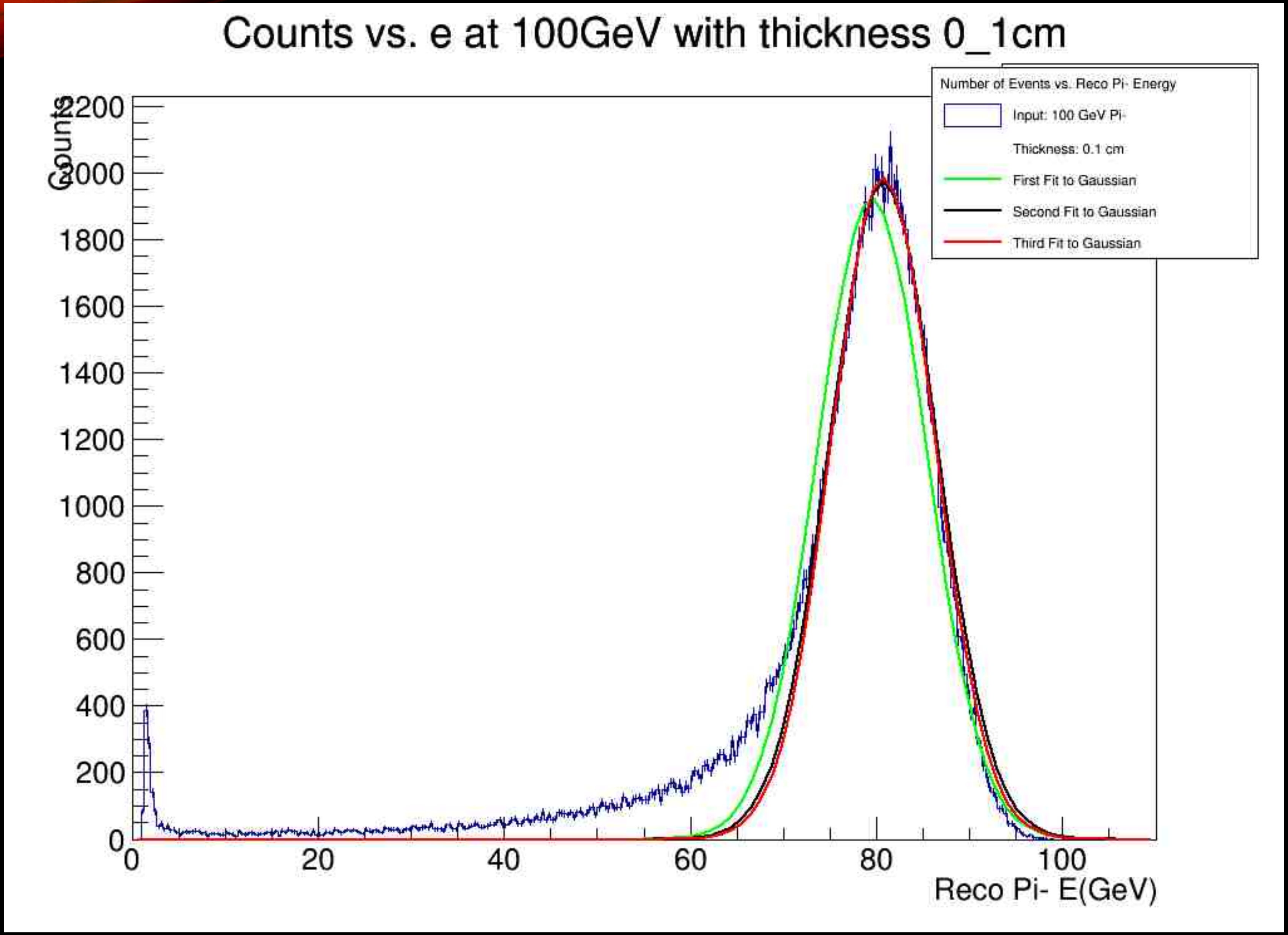

Counts vs. e at 80GeV with thickness 0_1cm
Number of Events vs. Reco Pi- Energy
Input: 80 GeV Pi-
Thickness: 0.1 cm
First Fit to Gaussian
Second Fit to Gaussian
Third Fit to Gaussian
Counts
Reco Pi- E(GeV)


E_Mean/E_input vs. Flux Return Thickness
E_Mean/E_Input
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
5
10
15
20
25
Thickness (cm)
E_mean/E_input vs. FR_Length
Thickness (cm) | E_Mean/100
20.4 | 0.581283
15.0 | 0.634606
10.2 | 0.680179
7.5 | 0.701777
5.1 | 0.720067
2.55 | 0.736784
0.1 | 0.751086


E_RMS/E_input vs. Flux Return Thickness
E_RMS/E_Input
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
5
10
15
20
25
Thickness (cm)
E_RMS/E_input vs. FR_Length
Thickness (cm) | E_RMS/100
20.4 | 0.169417
15.0 | 0.151064
10.2 | 0.137052
7.5 | 0.133507
5.1 | 0.132959
2.55 | 0.138793
0.1 | 0.149017
$\sigma_{natural}$/E_Fit_Mean (5.54/80.79)


E_FR_p_Mean/E_Input vs. Flux Return Thickness
E_FR_p_Mean/E_Input
Thickness (cm)
E_mean/E_input vs. FR_Length
Thickness (cm) | E_Mean/100
20.4 | 0.225609
15.0 | 0.158655
10.2 | 0.102124
7.5 | 0.0729188
5.1 | 0.0481534
2.55 | 0.0232416
0.1 | 0.000661317


E_FR_p_RMS/E_Input vs. Flux Return Thickness
E_FR_p_RMS/E_Input
Thickness (cm)
E_RMS/E_input vs. FR_Length
Thickness (cm) | E_RMS/100
20.4 | 0.180352
15.0 | 0.145535
10.2 | 0.105828
7.5 | 0.0819509
5.1 | 0.0573884
2.55 | 0.0291523
0.1 | 0.000859755
$\sigma_{natural}$/E_Fit_Mean (5.54/80.79)


Counts vs. e at 100GeV with thickness 0_1cm
Number of Events vs. Reco Pi- Energy
Input: 100 GeV Pi-
Thickness: 0.1 cm
First Fit to Gaussian
Second Fit to Gaussian
Third Fit to Gaussian
Counts
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0
20
40
60
80
100
Reco Pi- E(GeV)